Building a Decision Support System: The Mythical Man-Month Revisited

Peter G. W. Keen
Thomas J. Gambino

May 1980

CISR No. 57
Sloan WP No. 1132-80

Building a Decision Support System: The Mythical Man-Month Revisited

Peter G. W. Keen
Thomas J. Gambino

May 1980

CISR No. 57
Sloan WP No. 1132-80

to appear as a chapter in Building Decision Support Systems, edited by J. F. Bennett, Addison-Wesley Series on Decision Support.

TABLE OF CONTENTS

FIGURES

TABLE

1. Introduction

1.1 Overview

This paper describes the development of a Decision Support System, from its beginning as part of a research project through to the implementation of it as a commercial product used by six state agencies and public sector consulting groups. The system was designed by individuals with a long-standing involvement with DSS. As such, it provided an excellent opportunity to test the conventional wisdom on principles and techniques for DSS design.

We had clear expectations as to what would be easy and what would be hard to implement. We wanted to see if the DSS field is at a stage where one can give builders reliable rules of thumb -- not a cookbook, but the sort of pragmatic advice that would be welcomed by a capable systems analyst, consultant or programmer setting out for the first time to deliver an interactive computer system to support decision makers in a complex task.

ISSPA (Interactive Support System for Policy Analysts) is a DSS, written in APL, that supports administrators, analysts and researchers concerned with public policy issues at the state and local level. The initial application which this paper discusses is in the area of school finance: the funding of public education in individual states. However, ISSPA is of general relevance to planning and policy making in both the public and private sectors.[1]

The development strategy was based on principles of adaptive design, derived from the recommendations of several researchers and practitioners (see Section 5).

These principles assume that the "final" system must evolve through usage and learning. Rather than focus on functional specifications, the designer relies on a prototype to:

(1) Find out quickly what is important to the user as opposed to what the designer thinks ought to be important;

(2) provide something concrete for the user to react to and experiment with; and

(3) define a clear architecture for the DSS, so that it can easily be modified and evolved.

The prototype is a real system, not a mock-up or experiment. It provides the base for learning-by-using.

As well as prototypes, adaptive design emphasizes:

(1) Careful attention to the user-DSS dialog, and thus to the design of the software interface;

(2) the importance of user learning, in terms of the evolution of the system and the need for flexibility in the DSS and responsive service by the system builders;

(3) getting started, rather than getting finished; and

(4) a command-based structure; ISSPA is built up of APL functions that directly correspond to the action words or the "verbs" users employ in their own problem-solving. A verb is a statement "do this", such as "give me descriptive statistics", which ISSPA performs with a DESCRIBE function.

1.2 The Mythical Man-Month

The adaptive design approach used with ISSPA, and the choice of

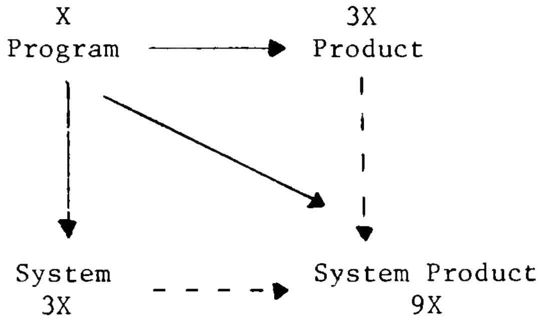
APL, reflect a hypothesis that is the main topic of this chapter:

> *Adaptive design resolves the problem of the mythical man-month*.

The mythical man-month is F.P. Brooks' summary[2] of the discrepancy bebetween the expected and actual effort required to develop software products. Designers estimate the time for completion in terms of man-months; their projections almost invariably turn out to be badly wrong and the system often does not work.

Brooks identifies a number of explanations for the widespread problems in planning for and delivering software systems. Assessments of man-months are often based on the number of lines of code. However, program coding is only 10% of the total effort. Moreover, if X is the effort required to write and test a program, 3X is needed to make it into a program *product* and 9X to integrate it into a *system* product (Figure 1).

FIGURE I: Brook's Assessment of Relative Programming Effort



Making a program into a product involves documentation, additional testing to ensure "robustness" (i.e., it should be able to handle inputs and uses outside the range of the initial special-purpose program), error-handling routines, etc. Integrating a program into a system requires substantial testing of linkages, and often additional code must be written to ensure consistency.

Brooks recommends several techniques to solve the problem of the mythical man-month. He emphasizes the importance of a clear design architecture, the use of "sharp tools" (including APL), and systematic testing procedures.

We were particularly concerned about the mythical man-month since we wished to make ISSPA into a system product and had an extremely limited budget. In essence, we started with a set of hypotheses about DSS development, in terms of adaptive design, system architecture, APL, and the mythical man-month. The rest of this chapter describes our experiences, focussing on the surprises. We found that:

(1) The principles of adaptive design, which are unique to the DSS faith and stand in sharp contrast to the methods of the systems development life cycle, hold up well. Given APL as a tool, we have been able to evolve a complex system out of simple components and respond quickly to our users' changing needs.

(2) We underestimated the importance of having skilled users; much of the testing process relies on them.

(3) While APL immensely speeds up the development process, it has some hidden costs. It is extremely difficult, even for expert programmers, to estimate the relative efficiency of the source code. ISSPA is expensive to run and we found that rewritting some sections of the code reduced the processing cost by a factor of 20. We suspect that many super-high-level languages share with APL a characteristic we term opaqueness: the surface (the source code) gives no clear indication of depths (machine-level).

(4) Brook's estimate of 9X seems to hold. Even with APL, adaptive design and a highly skilled programmer, the initial development effort has to be supplemented by continuous attention to improving the usability of the DSS. Of course, since APL reduces X, it also makes the total effort -- 9X -- acceptable.

2. School Financial Policy Issues

Since the early 1970's, the funding of public schools has been a major legislative and judicial issue in at least half the states in the country.[3] The Serrano case in California (1973) established that a child's opportunity for education -- expressed in terms of expenditures per pupil in each school district in the state -- should not be determined by his or her parents' and neighbors' wealth. Towns with high wealth and property values can raise large revenues for less effort than poor ones. Since local property taxes are the major component of school revenues, this has resulted in huge disparities between neighboring districts. To resolve this inequity, the state must both limit rich districts' expenditures and provide substantial aid to poor ones.

The main result of school finance reform has been to place responsibility on the state legislature and executive to determine the "formula", the set of precise equations on which each district's state aid is based. This requires fundamental rather than incremental analysis. A school district can base next year's plans on a budgeting procedure which largely examines cost increases (especially in teachers' salaries). The voters in the town will approve -- or, increasingly in recent years, reject -- the budget. Similarly, in states where school finance is not a major issue, the legislature can adjust last year's formula, increasing the basic state aid by, say, 8%.

This incremental process, which has worked reasonably well for a century, breaks down when a judge declares the state's existing system unconstitutional or when school finance becomes a "hot" issue because of taxpayer revolts or when inflation affects the ability of local districts to raise adequate revenues. There must then be fundamental, not incremental analysis of policy choices.

Unfortunately, the professional staff responsible for such analysis can rarely provide it. The whole aim of ISSPA is to break through the technical constraints they face, but many organizational ones remain. The key problem is that the whole system has always relied on incrementalism. There is no policy focus. Even when a court decision forces rethinking, legislators are mainly concerned with the "bottom line", the exact impact of a proposed formula on each of their constituent districts. This "costing out" of the formula leads to a narrow focus; the planning horizon is next year and longer-term qualitative issues are ignored.

The key issues in school finance concern data. It is a "numbers" game with lengthy arguments about who has the right figures. The state aid formula is generally based on a variety of data: attendance by grade, enrollment (which is not necessarily even close to attendance), local tax rates and revenues, transportation expenditures, special and vocational education information, etc., etc. School finance is a morass of numbers. In New York, for example, every local school superintendent must supply the state with up to 1,200 pages of data a year.

Control over this data is the major source of influence for the department of education, which is generally a poor step-child in state government. A few states have effective collection, control and reporting procedures, but on the whole, the data management process is clumsy and inefficient. There is a shortage of programmers. Low salaries and lack of hardware, management and training mean the policy analysts' major problem is access to high quality information.

These analysts are mainly legislative staff or professionals working for executive fiscal and budget agencies. Their responsibilities vary; they are partly watchdogs who monitor other parts of government (legislative or executive). They may initiate policy alternatives. Above all, they evaluate information on the current state aid system and on competing proposals for change. In general, the only computer-based aids available to them are SPSS (the standard Statistical Package for the Social Sciences) and limited batch "simulations" which do little more than calculate what each school district would have received last year had a proposed formula been used. Only a few states have more advanced tools. These tend to be expensive but highly valued by their users.

While legislative debates on school finance are limited to incremental analysis and the bottom line, the policy issues are complex. There is a rich research literature on measures of equity and alternative structures for a formula (foundation, guaranteed yield and pupil weighting), and the field has an esoteric jargon -- recaptures, save harmless, mills, and caps. The gap between the research concepts and the practice of policy analysts is huge.

ISSPA is intended to bridge the gap, to provide analysts with a "portable technology" that can help them add a real policy focus to school finance. Since access to information is the key to effective analysis, and even more, to influencing the legislative debate, ISSPA is designed to allow fast and flexible manipulation and display of information. It is a DSS for policy analysts not for policy analysis.

The state department of education often has a monopoly on data and data processing. It is also difficult for analysts to get appropriations for computer resources -- the centralized data processing unit can generally thwart local efforts to use other services. ISSPA had to be "portable". A portable technology is one that can be easily transferred and maintained. Portability includes:

(1) low cost; even $10,000 may be too expensive to justify, regardless of potential payoff -- if it involves a capital investment proposal and legislative approval;

(2) installation; given the frequent organizational isolation of analysts and the hostility of the data processing unit, it must be easy to build and update the ISSPA database and to bring up the DSS;

(3) ease of use and elimination of the need for training; the analysts have little experience with computers; it was important to make ISSPA self-explanatory;

(4) evolution; one long-term aim is to use ISSPA as a means of translating research concepts into analytic techniques. This means ongoing development; it is essential that users be able to get access to -- and contribute to -- the results.

Portability is as much a political as a technical concept.

3. ISSPA Design Features

3.1 Introduction

ISSPA is a command-driven system. There are five categories of command:

(1) data management

(2) data manipulation

(3) data display and reporting

(4) statistical analysis

(5) user-system linkages (e.g., 'help' commands)

Conceptually, the database is a matrix in the form:

planning units (rows x variables (columns))[4]

There is no fixed limit on either the rows or columns; ISSPA fills up the workspace with variables (via the CHOOSE command) until it is full. Labels for rows and columns may be of any length; users are not constrained to or muddled by uncommunicative mnemonics. In a typical school finance application, the database contains 500-600 variables for each of 500-750 planning units (school districts).

We deliberately chose a simple data structure and approach to data management for ISSPA. Our assumption was that policy analysis largely involves exploring and manipulating a small amount of high quality data, and that analysts think of the data as a simple table of values.

Commands in ISSPA are simple and kept as close to the users' vocabulary as possible. Almost all DSS claim to be English-like, and easy to learn and use. The evidence that ISSPA is indeed so is that users have been able to operate the system, drawing on most of its commands, with under an hour of training. The training is simply a one-hour demonstration. There are currently almost 50 commands; the initial system, put into use seven months ago, contained 22. Table 1 lists the commands, with brief comments on how they evolved.

Considerable effort was put into the design of the user-system interface. Conventions were kept to a minimum. Most commands involve typing a single word, which is generally self-explanatory, such as LIST, PLOT, REGRESS, DEFINE or COUNTIF. A structured dialog is used within the more complex commands; ISSPA prompts the user, in a fixed sequence: "DO YOU WANT A OR B?"

The only conventions which take time to learn and use concern CHOOSing variables and variable identifiers. Since the database may be of any size, only a part of it can be in the workspace at any time. Users are told to view the DSS as a scratchpad. The commands operate on whatever is in the scratchpad. The user CHOOSEs which variables to bring in from disk (see Figure 2). We assumed that this would not be constrictive since users will rarely want, or be able, to deal with more than 10-20 variables at the same time (see also Morton, Carlson and Sutton).[5]

Labels and mnemonics for variables are cumbersome to use and hard to remember, especially since an ISSPA database often contains over 600 variables. The convention used in ISSPA is that variables are referenced by either a permanent identifier Vxxx, set up when the database is created, or by a temporary number Axx, showing the variable's location in the workspace ('A'xx = active variable number xx).

While analysts found their convention reasonably easy to accept, they still wished to define their own labels at least for those variables they used frequently. We added a SYNONYM facility so that now variables can be referred to by their V-number, A-number or a one-word user-supplied label.

TABLE 1: ISSPA COMMANDS

	(1) Library?	(2) Modify Dialog?	(3) Extend/ Improve?	(4) System Command?
1. Initial Commands				
CHOOSE/UNCHOOSE				x
COMMANDS				x
CORRELATE	x	x	x	
COUNTIF				
CROSSTAB	x	x		
DEFINE/REDEFINE				
DESCRIBE				
DIRECTORY				x
DONE				x
ENVIRONMENT				x
FREQUENCIES	x	x	x	
HEAD				
HISTO	x			
LIST			x	
NTILES				
RANK			x	
REGRESS	x	x	x	
SCATTER	x			
TOP/BOTTOM				

2. Added when Version 0 made available to users

	(1)	(2)	(3)	(4)
ADD/DROP DATABASE				
CLEAR				x
FORMAT				
GROUPIF/UNGROUP			x	
PARTIAL CORR	x			
RANGE, MIN, MAX, MEAN, MEDIAN, TOTAL				
SCALE/RESCALE		x		
WAVERAGE				

3. Added at user request

COMMAND COST/SESSION COST				x
CONTINUE		x		x
DISPLAY .... FOR UNITS		x		
SELECT UNITS		x		
SYNONYM				
VARS		x		x
WHAT IS				x
YEARS				
* SAMPLE				

4. User-defined	(1)	(2)	(3)	(4)
OHIO				
WTILES			x	
5. "Evolved" commands added by designers				
BOXPLOT				
CONDENSE				
EQUITY				
STEMLEAF				
6. Extended Capability				
IMPS				

(1) library? = taken from APL public library?

(2) modify dialog? = were substantial changes made to user-DSS dialog in response to user reactions?

(3) extend/improve? = were extensions or improvements made to the command, in terms of function not dialog?

(4) system command? = is this a general system command rather than user command?

FIGURE 2 - CHOOSING ISSPA VARIABLES

(User responses are underlined)

```
COMMAND: DIRECTORY
THE AVAILABLE DATA CATEGORIES ARE:
    1 ENROLLMENT
    2 REVENUE
    3 EXPENDITURES
    4 STAFF
    5 TAX BASE AND TAX RATE
    6 DISTRICT CHARACTERISTICS
```

(1) DIRECTORY lists variable groups in the permanent database

```
EXPLORE ANY GROUP ('NO')?   ENROLLMENT
V101  TOTAL ADM 79
V102  TOTAL ADM 78
V103  SPECIAL EDUCATION ADM 79
V104  SPECIAL EDUCATION ADM 78
```

(2) V101 is permanent numeric identifier number, and TOTAL ADM 79 its permanent discriptor

```
EXPLORE ANY GROUP ('NO')?   2
V201  TOTAL REVENUE 79
V202  TOTAL REVENUE 78
V203  LOCAL REVENUE 79
V204  LOCAL REVENUE 78
V205  STATE BASIC AID 79
V206  STATE BASIC AID 78
V207  SPECIAL EDUCATION AID 79
V208  SPECIAL EDUCATION AID 78
V209  OTHER REVENUE 79
V210  OTHER REVENUE 78
```

(3) Group 2, REVENUE, has 10 variables

```
COMMAND: VARS

* * *NO ACTIVE VARIABLES* * *
```

(4) the workspace is currently empty

```
COMMAND: CHOOSE
GROUP OR ITEM?   GROUP
GROUP NAME (STOP)?   ENROLLMENT
GROUP NAME (STOP)?   STOP

CURRENT NUMBER OF ACTIVE VARIABLES:  4
```

(5) CHOOSing the ENROLLMENT group results in four active variables

```
COMMAND: VARS
THE ACTIVE VARIABLES ARE:
A1   V101   TOTADM79        TOTAL ADM 79
A2   V102   TOTADM78        TOTAL ADM 78
A3   V103   SPECEDADM79     SPECIAL EDUCATION ADM 79
A4   V104   SPECEDADM78     SPECIAL EDUCATION ADM 78
```

(6) an active variable may be referenced by its A-number, V-number or synonym (user-supplied) to, (e.g., A1, V101 or TOTADM79) may be used interchangeably with any command

```
COMMAND: CHOOSE
GROUP OR ITEM?   ITEM
ENTER VARIABLE (V) NUMBER ('STOP'):?   V201
ENTER VARIABLE (V) NUMBER ('STOP'):?   V301
ENTER VARIABLE (V) NUMBER ('STOP'):?   STOP

CURRENT NUMBER OF ACTIVE VARIABLES:  6
```

(7) CHOOSE individual variables rather than a group

```
COMMAND: VARS
THE ACTIVE VARIABLES ARE:
A1   V101   TOTADM79        TOTAL ADM 79
A2   V102   TOTADM78        TOTAL ADM 78
A3   V103   SPECEDADM79     SPECIAL EDUCATION ADM 79
A4   V104   SPECEDADM78     SPECIAL EDUCATION ADM 78
A5   V201   TOTREV79        TOTAL REVENUE 79
A6   V301   TOTOPEXP79      TOTAL OPERATING EXP. 79
```

```
COMMAND: RANK V201,V301,V101 BY V101
•PP•

                                      TOTAL         TOTAL         TOTAL
                                     REVENUE       OP. EXP         ADM
                                      1979          1979           1979
                                  ------------  ------------  -----------

 1. 0301 BIG CITY S.D.             186,951,769   171,591,450      99,219
 2. 0501 CAPITOL CITY S.D.         130,481,187   109,444,927      80,330
 3. 0101 RIVER CITY S.D.            92,870,956    85,310,671      56,970
 4. 0502 INDUSTRY CITY S.D.         83,791,031    64,457,113      46,897
 5. 0204 LANCASTER CITY S.D.        13,337,333     9,871,846       7,514
 6. 0206 XENIA CITY S.D.            10,415,333     8,324,413       6,608
 7. 0102 LAKOTA LOCAL S.D.           8,507,302     6,396,336       6,474
 8. 0104 ZANESVILLE CITY S.D.        9,310,625     6,963,875       5,810
 9. 0503 BEDFORD CITY S.D.          13,490,072     9,250,840       5,717
10. 0208 TROY CITY S.D.              7,319,274     5,213,457       4,768
11. 0103 MIAMISBURG CITY S.D.        7,061,369     5,365,450       4,347
12. 0205 LOGAN CITY S.D.             4,787,049     3,924,081       4,036
13. 0201 ELIDA LOCAL S.D.            3,856,170     2,996,168       3,137
14. 0202 GALLIA COUNTY LOCAL         4,852,539     3,949,600       3,041
15. 0203 LAKEVIEW LOCAL S.D.         3,328,556     2,650,652       2,230
16. 0209 THREE RIVERS LOCAL          4,189,051     2,867,830       2,030
17. 0403 MIAMI EAST LOCAL S.D        2,153,682     1,623,376       1,623
18. 0207 WINDHAM EX VILL S.D.        2,388,170     1,623,665       1,586
19. 0102 BEACHWOOD CITY S.D.         6,025,259     4,347,745       1,535
20. 0504 GRANDVIEW HEIGHTS           2,926,374     2,157,401       1,341
21. 0401 LISBON EX VILL S.D.         1,619,886     1,317,526       1,339
22. 0401 HUNTINGTON LOCAL S.D        1,302,025     1,172,409       1,250
23. 0106 MONROEVILLE LOCAL           1,207,650       865,555         771
24. 0105 WOLF CREEK LOCAL S.D          977,054       885,322         704
25. 0210 NEW KNOXVILLE LOCAL           635,392       472,290         395
```

(8) Sample Command RANK A5, A6, A1 by A1 would have same effect

We allowed variable names to be of any length, to ensure that reports would be meaningful and clear. If users -- or the legislator or public interest groups for whom they prepare analysis -- think of a variable as "GUARANTEED YIELD, GOVERNOR'S PROPOSAL", then that is what must appear on reports, not "GY, GVR". Obviously, by providing maximum flexibility on variable labels, we had to find a compact and efficient (from the user's perspective) mode of reference.

3.2 Program Structure

The program structure of ISSPA is relatively simple in concept. There are three separate components (See Figure 3):

(1) User-system interface;

(2) commands ("LIST", "REGRESS", etc.); and

(3) data management routines, transparent to the user.

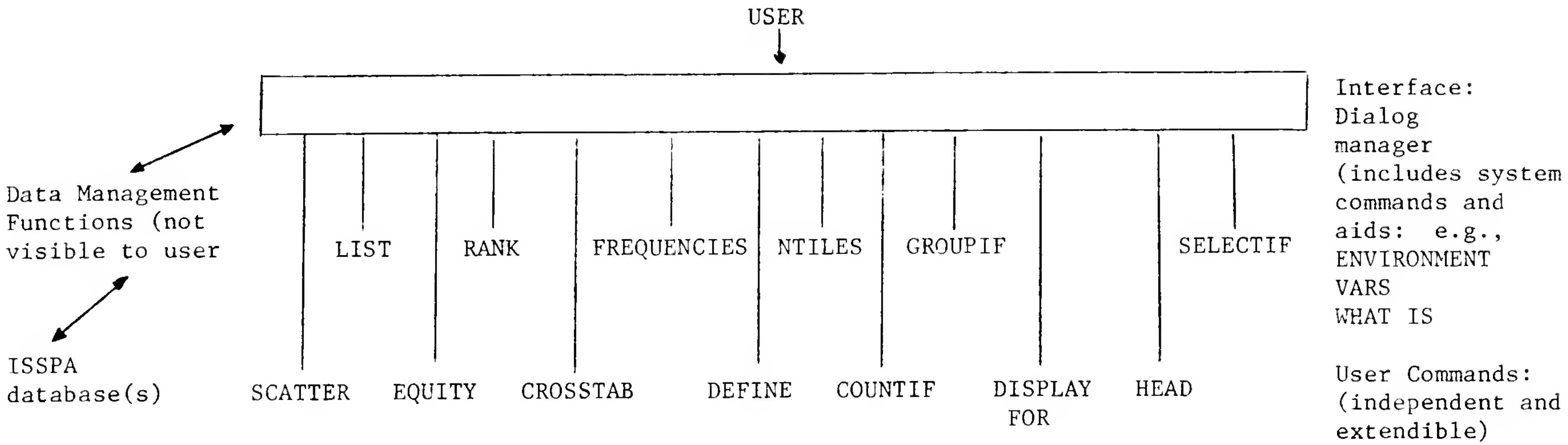
Most of the initial effort went to defining the interface, which handles the dialog between the users and the system and thus strongly determines if they will view the DSS as friendly and easy to use. Once the initial system was released for use, significant effort was needed for the data management routines. Many of the commands use APL functions from public libraries (see Section 6), especially those for statistical analysis.

Brooks draws attention to the "architecture" of a system. The command-based structure we used for ISSPA meets many of his recommendations:

(1) It reflects a top-down approach and the dialog-manager is independent of the commands and data management routines;

(2) each command is fully independent of the other; a new one can be added to ISSPA with no change to the logic of the dialog manager or to any other command;

FIGURE 3: ISSPA PROGRAM STRUCTURE



(3) our design methodology is a form of "stepwise refinement". We implemented an initial version of a routine and refined it on the basis of users' experiences and reactions.

The convention for naming variables illustrates this last point. We started by deciding that there would be no restrictions on variable labels for reports. This meant that the label could not be used as the variable indentifier, since this could mean typing 50 characters or more. We struggled to defind a compact method and initially tried the V-number approach. We added A-numbers to deal with variables defined from other variables (e.g., DEFINE (V101 + V109) ÷ V217).

The initial system was used for several months before we extended it. We added (Figure 4):

(1) SYNONYM;

(2) WHAT IS; to allow easy identification of a variable;

(3) IDENTIFIER: this lists the full label for any A-number, V-number or synonym;

(4) VARS; this shows the identifiers for all the variables currently active.

Adaptive design assumes that such extensions will be added _as a direct result of system usage_. One cannot predict in advance exactly what will be needed. The early users of ISSPA in effect taught _us_.

4. The Development Process

4.1 Introduction

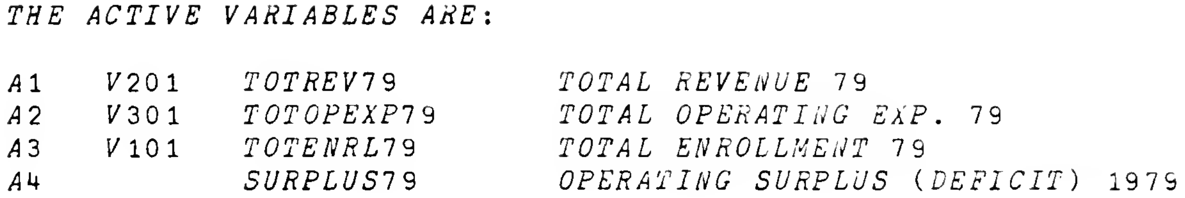
This section briefly summarizes the sequence of the development process. Adaptive design is based on rules of thumb. We present the rules as we proceed and list them at the end of the narrative.

FIGURE 4: IDENTIFYING VARIABLES IN ISSPA

(User Inputs Underlined)

```
(1)  SYNONYM    V404

     CURRENT SYNONYM:  LOCAL TAX BASE

     NEW SYNONYM:  LOCT


     SYNONYM    A11

     NO CURRENT SYNONYMS

     NEW SYNONYM:  FEDTAX79


(2)  WHAT IS    TOTENRL78

     A1    V102    TOTENRL78    TOTAL ENROLLMENT 78


(3)  IDENTIFIER    A1

     TOTAL ENROLLMENT 78
```

(4) VARS



```
THE ACTIVE VARIABLES ARE:

A1    V201    TOTREV79           TOTAL REVENUE 79
A2    V301    TOTOPEXP79         TOTAL OPERATING EXP. 79
A3    V101    TOTENRL79          TOTAL ENROLLMENT 79
A4            SURPLUS79          OPERATING SURPLUS (DEFICIT) 1979
```

The initial system took roughly 70 hours of effort on the part of the programmer (Gambino). Keen, in an ongoing research study, had spent six months studying the design and use of the computer models and information systems in state government agencies concerned with school finance policy making. The computer systems available to policy analysts in most states were cumbersome and very limited in scope. The analysts complained of their lack of flexibility and of the unavailability of data. Generally, they were unable to get programs written to produce special reports; the data processing staff were unresponsive, overworked or incompetent. A few states had useful interactive systems, but these were expensive ($200,000 - $1,000,000).

The initial design aim for ISSPA was to show that a simple, general, flexible and cheap DSS could be built that would meet the analysts' needs and also facilitate better and more extensive exploration of policy issues. Limited funds were available for the initial system. From the start, however, ISSPA was intended to be a system product in Brooks' sense of the term; it was expected that there would be sufficient demand for such a system that funds would be available for continued development.

The development fell into three distinct phases:

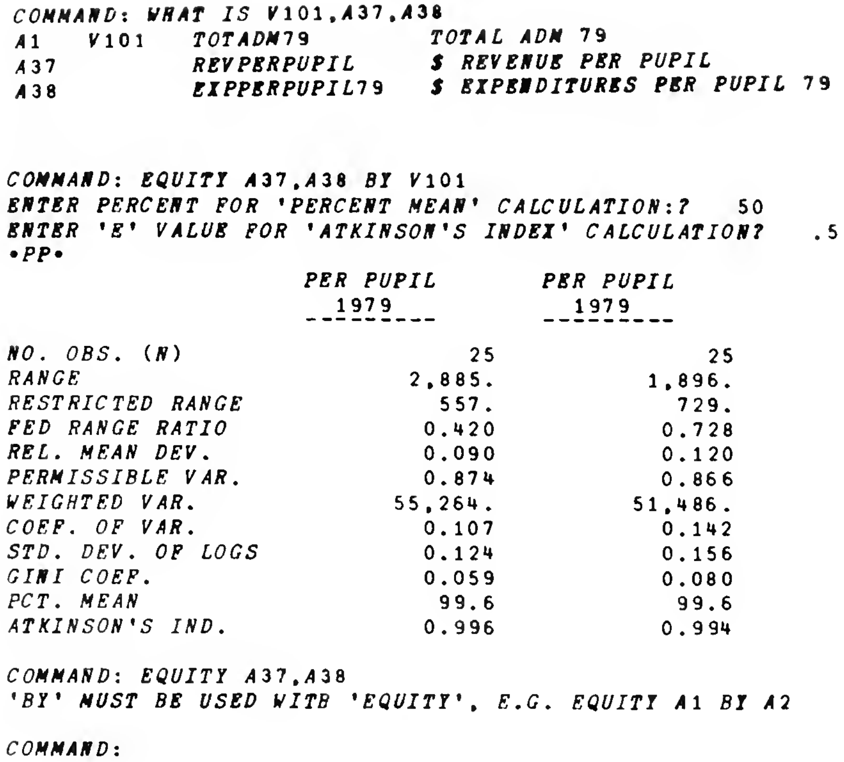
(1) Phase 1: build the initial system, Version 0.

(2) Phase 2: extend it, adding new commands and improving existing ones in response to users' reactions.

(3) Phase 3: create the system product that is portable, stable and documented.

Each phase posed different challenges.

FIGURE 5: EQUITY COMMAND



```
COMMAND: WHAT IS V101,A37,A38
A1    V101    TOTADM79          TOTAL ADM 79
A37           REVPERPUPIL       $ REVENUE PER PUPIL
A38           EXPPERPUPIL79     $ EXPENDITURES PER PUPIL 79


COMMAND: EQUITY A37,A38 BY V101
ENTER PERCENT FOR 'PERCENT MEAN' CALCULATION:?   50
ENTER 'E' VALUE FOR 'ATKINSON'S INDEX' CALCULATION?   .5
•PP•
                         PER PUPIL        PER PUPIL
                          1979             1979
                         ---------        ---------

NO. OBS. (N)                     25               25
RANGE                        2,885.           1,896.
RESTRICTED RANGE               557.             729.
FED RANGE RATIO               0.420            0.728
REL. MEAN DEV.                0.090            0.120
PERMISSIBLE VAR.              0.874            0.866
WEIGHTED VAR.               55,264.          51,486.
COEF. OF VAR.                 0.107            0.142
STD. DEV. OF LOGS             0.124            0.156
GINI COEF.                    0.059            0.080
PCT. MEAN                      99.6             99.6
ATKINSON'S IND.               0.996            0.994

COMMAND: EQUITY A37,A38
'BY' MUST BE USED WITH 'EQUITY', E.G. EQUITY A1 BY A2

COMMAND:
```

(1) (pp = position paper; system pauses till carriage return hit)

(2) "by" variable is weighting factor used to compute measures requiring weighting population

4.2 Phase 1: The First Meeting

At their first meeting, Keen and Gambino began by sketching out the user-system dialog. Keen, as the analyst, had a clear idea of the initial set of user verbs to be supported. For example, it was obvious that analysts relied heavily on rankings; e.g., they would create a report listing expenditure figures, with the district with the largest average revenues per pupil showed first. This became a command: "RANK .... BY".

Keen presented the verbs and Gambino suggested the exact dialog. Keen would respond to the recommendation; generally, it would be rejected if it was cumbersome or clumsy for a non-technical, inexperienced user.

The meeting lasted three hours. There was a constant give-and-take between analyst and technician. A general dialog was agreed on but not set in concrete. This dialog determined the nature of the data management routines. We had started by focussing on the representation of the data; it must appear to the user as a simple table of values. Each command must operate directly on the table, with no specific procedures needed on the part of the user to get, manipulate or update data.

It is worth noting that our approach was the opposite of standard systems analysis. We began from the outputs and worked back to the inputs, leaving the procedures to be specified later. This reflects our view that what happens at the terminal determines the "quality" of the DSS; to the user, the interface is the system. Most programmers focus on defining the input data and then the procedures, leaving the outputs to last.

This strategy also allowed Gambino, who was completely unfamiliar with school finance, to quickly learn a great deal about the intended users. Many programmers have a naive view of the user. Indeed, the "user" is often only an abstraction. From the start, all our design effort emphasized what the user would say and see. The "quality" of the DSS was defined in terms of ease of use, lucidity and gracefulness. Far from being an abstraction, the user was a real presence.

This initial phase of the development process reflects a key and reliable rule-of-thumb:

Rule 1: Design the dialog first. Forget about input files, functional capabilities, etc.:

R.1(a): Define what the user says and sees at the terminal.

R.1(b): Define the representation of the data· what does it look like to the user?

4.3 Initial Commands

Keen distinguishes between usefulness and usability in a DSS.[6] Usefulness relates to the capabilities of the system: models, retrieval facilities and report routines. Usability refers to the user-system dialog. Our first rule of thumb stresses usability. Obviously, though the initial system has to contain something worth using.

The link between users' verbs and DSS commands is a key one for our design strategy (see Section 6). Understanding the user involves identifying his or her verbs. The verbs provide design criteria for the commands that constitute the useful components of ISSPA. We defined two types of command:

(1) Those based on generic verbs; and

(2) those that are special-purpose.

Generic verbs are the ones common to most problem-solving and analysis, and that are required in most DSS. For example, any task involving data analysis needs a LIST, RANK and HISTO (gram) command. We identified a dozen generic commands, most of which could be provided with minimal programming.

Generic commands will already have been implemented in other systems. We chose to use APL partly because excellent public libraries are available on several computers. APL is a convenient language for borrowing routines since integrating them into a program requires very little effort. All the statistical routines in ISSPA come from public libraries. We have found that 2-8 hours are required to modify, integrate and test a routine from a library. Since it has already been at least partially, and in most cases entirely, debugged, we save much of the 9X of effort Brooks identifies. The main modifications needed in adding a function to ISSPA involve the user-system dialog. Many of the designers of APL programs show little sensitivity to the user (see Section 7).

Most special-purpose commands obviously must be programmed. For policy analysis in general, we identified well over 20 special-purpose verbs and for school finance another 10. The general verbs largely related to statistical techniques and measures and the school finance ones to measures of equity and approaches to comparing and ranking school districts.

Examples of the various types of command we identified for potential inclusion in the initial version are:

(1) generic: LIST, RANK, DESCRIBE (descriptive statistics), HISTO (gram), DEFINE (new variable), FREQUENCIES, ADD (to) DATABASE.

(2) special-purpose:

  (a) policy analysis: SELECT UNITS, COUNTIF, BOTTOM, NTILES, GROUP, REGRESS, ANOVA

  (b) school finance: EQUITY, (equity measures), GINI, LORENZ[7]

We put priorities on the commands. This was done informally and based on four criteria:

(1) The <u>priority to the user</u>; i.e., the extent to which this command reflected a verb the analysts rely on or would immediately find useful;

(2) <u>ease of implementation</u>; HISTO and REGRESS could be taken directly from an APL public library;

(3) <u>clarity of user-DSS dialog</u>; with REGRESS, we could lay out in advance a simple complete dialog. We found it hard to do so for ANOVA (analysis of variance) and thus left that for a later version; and

(4) <u>likelihood of acceptance</u>; we avoided trying to force unfamiliar or contentious routines on the user; we could -- and did -- add them later.

The focus on user verbs and the use of a command-based program structure were an effective and simple technique. Our ability to extend version 0 from 12 to 50 commands directly resulted from these rules of thumb:

<u>Rule 2</u>: Identify the users' special-purpose verbs.

<u>Rule 3</u>: Identify generic verbs, relevant to this DSS.

<u>Rule 4</u>: Translate the verbs into commands, and vice versa.

<u>Rule 5</u>: Check public libraries for off-the-shelf routines, especially for generic verbs.

Rule 6: Set priorities for implementing commands for version 0.

Rule 7: Support first, extend later; aim at giving the user something he or she will readily accept and add the less familiar, more complex capability later.

4.4 Version 0

A working system was available within 40 hours.[8] It contained the following user commands:

LIST, DESCRIBE, RANK, TOP, BOTTOM,
HISTO, REGRESSION, CORRELATE and NTILES
(e.g., 10 NTILES = deciles, 4 NTILES - quartiles)

The regression, histogram and correlation routines were taken from a public library. Version 0 included other commands needed to manage the user-system dialog or improve the usability of the DSS; e.g., DIRECTORY, CHOOSE, ENVIRONMENT.

When the preliminary system was ready, we spent substantial time (10 hours) improving what the users saw on the terminal. The major changes that needed to be made concerned the formats of the outputs. Whereas functional specifications involve laying out a report format in some detail, adaptive design is similar to the concept of stepwise refinement. Instead of asking users "What do you want?", we said "How do you like this?".[9]

We entirely redesigned the dialog and style of the outputs by playing with the system, prior to showing it to potential users. After an additional 20 hours of programming effort, we had an operational system (70 hours in total), with over 30 commands. This was made available to a senior policy analyst and his assistant in a large state's education agency. Over the next three months, they worked with the system and many extensions and modifications were made (see 4.5 below).

This first phase of development worked out well. Even at commercial rates for programming and computer time, we had spent under $4,000. We demonstrated the system in several states; instead of trying to sell an idea, we could show a complete working DSS. We kept careful track of the development process up to this stage; we wanted to check our experience with the general conclusions of Ness, Courbon et al., and Grajew and Tolovi.[10] We agree with Grajew and Tolovi's estimate that the initial system, which will then evolve through usage, can be built for under $10,000 in less than 16 weeks.

This is an important point, since:

(a) It reduces the user's risk and encourages experiment; a DSS becomes more of an R&D effort than a capital investment; and

(b) the lead time between the initial proposal and a usable system is short enough that the users' enthusiasm and momentum are not dissipated.

Version 0 was simple but not simplistic. The analysts who saw it were impressed by how easy ISSPA is to use and by its power:

Rule 8: Keep it simple from the start; aim for a few useful commands for version 0 and evolve a complex DSS out of simple components.

Rule 9: Deliver version 0 quickly and cheaply.

Rule 10: Make sure version 0 sells itself; it must be easy to use, the outputs clear and the dialog self-explanatory.

4.5 Phase 2: Bringing in the Users

In a sense, potential users of ISSPA were involved from the start. Keen's and Clark's studies of school finance had included surveys and interviews with analysts, legislators and administrators in eleven states. They discussed the idea of ISSPA with several experienced analysts, who worked with version 0 and played a major role in the evolution of ISSPA.[11]

We were extremely selective in looking for potential users. Since version 0 was intendedly only a start and not the final system, the skills and creativity of the early users would strongly influence the quality of the full system. Adaptive design _relies_ on good users.

Our first user was a widely-respected senior analyst in a large mid-western state. He was impressed with ISSPA and, with the help of a subordinate who had some knowledge of computers, began using it after one demonstration. There was no user manual: while this led to occasional problems, ISSPA is largely self-explanatory.[12]

We wanted the initial users to react to ISSPA and to test it. We did not want them to have to debug it. Debugging means finding errors; testing, in our sense, means seeing how well the system works, deciding what needs to be changed or added and, above all, critiquing the quality of the interface.

Version 0 was _not_ bug-free. We had left the complex issue of data management till last. We had carefully designed the _representation_ of the data -- how it looked to the user. As we built the data management routines, we introduced errors; what worked on Monday bombed for no apparent reason on Tuesday.

In retrospect, we should not have released version 0 until we had implemented a reasonably complete initial version of these routines. Some users get very unhappy very quickly with an unstable system. (However, they are also very tolerant of errors in the first release of a new command.)

As we expected, we learnt a lot from the early users. One episode was instructive. NTILES is a command that identifies the cutpoints that break the distribution of values into equal groups; e.g., 5 NTILES REVENUES lists quintiles, 10 NTILES deciles, etc. This was an obvious command to include in version 0, since in school finance court cases and legislative reports, a frequent comparison is made between, say, the top 10% and the bottom 10% of school districts. We assumed that the NTILES command would be seen by analysts as helpful, but not unusual.

In fact, NTILES was enough in itself to sell the merits of ISSPA. In most states, calculations of deciles are done by hand. SPSS, the standard statistical package analysts use, does not allow observations to be reordered. In several states, we found instances where COBOL programs had been written to print the 5%, 10%, 25%, 33%, ... 95% intervals for a distribution, but only for specified variables. The idea that such programs could be generalized and on-line access provided came as a surprise to many analysts.

Once the analysts had access to a general routine like NTILES, they used it in new ways and developed new ideas from it. For example, WTILES adds an equity measure to the simple deciles or quantiles NTILES provides (WTILES stands for Weighted NTILES). It allows the analyst to answer such questions as "What are the 1978 expenditures for the bottom 10% and bottom 90% of the students in the state?". The analyst who defined WTILES used it as the basis for a major report on school finance equity and felt that the analysis could not have been done previously.

The sequence of events summarized above occurred several other times. The general pattern was:

(1) Data processing had provided a specific solution to a specific problem;

(2) we identified the general verb relevant to the problem;

(3) we provided a flexible command;

(4) use of the command stimulated a distinctive new idea or approach; and

(5) we added the resulting user-defined command to ISSPA.

We strongly feel that this pattern is a central aspect of DSS development. Keen studied over 20 published case descriptions of DSS and concluded that in many instances, the most effective uses of the systems were both entirely different from the intended ones and could not have been predicted beforehand (see Section 5).[13] Learning and evolution of system commands are a natural outcome of adaptive design.

Such learning requires skilled users. Throughout the second phase of the development of ISSPA, we found the users' role to be central; we had not anticipated their importance in testing. At one stage, we had users in five separate states. One of them was of immense value to us, one was close to a disaster. We feel sure that the experience provides a general lesson to DSS builders. Adaptive design provides a working system quickly. The designer realizes that there will be many things wrong with it and gains immensely from the users' reactions. If the users are not highly skilled in their own job and actively interested in the DSS, the designer does not get essential feedback.

A "working" system is one that has no obvious bugs. "*!39VW" or "SYNTAX ERROR" is clearly a bug, but $210 instead of the correct $160 is not. Because a DSS is intendedly a flexible tool, under the user's control, it does not have a set of "correct" inputs, procedures and outputs. Even in a standard data processing application, it is impossible to test all combinations. Flexibility, generality, ad hoc uses, and variety of inputs, commands and outputs compound the problem. Only a good user can alleviate it. User A (the good one) provided invaluable feedback. User Z either did not recognize errors or simply complained that "something's wrong"; the credibility of ISSPA suffered as a result. In several instances, legislators were given incorrect reports. The errors were subtle and only an expert on school finance could spot them. User Z was, reasonably enough, very bothered when errors were revealed but did little to uncover or cure them. User A sought them out.

What we learned from all this was that a distinguishing aspect of DSS development is that it is user-dependent:

(1) Adaptive design is an interactive process of learning and feedback between a _skilled_ user and a _skilled_ technician.

(2) the _user_ tests a DSS;

(3) many DSS bugs are unobtrusive and remain dormant until a user finds them;

(4) the range of functions exercised depends on the user. Bugs reveal themselves only by use. Only an imaginative, confident, involved user gives the DSS an adequate work out.

Rule 11: Pick a good user; look for someone who:

(a) has substantial knowledge of the task the DSS supports;

(b) has intellectual drive and curiosity;

(c) will take the initiative in testing and in evolving version 0; and

(d) enjoys being an innovator.[14]

During this second phase of development, ISSPA grew in scope and sophistication. Very few commands were left unchanged; many of the improvements were minor enhancements in formatting or ease of use. New commands were added that were specific to school finance (i.e., not based on generic verbs). For example, EQUITY (see Figure 5) provides 12 measures of the equity of an existing or proposed state aid plan. It is derived from a research paper by Berne[15] which has had substantial influence on school finance policy research but little on policy making. Whereas the initial commands supported analysts' existing processes, EQUITY was specifically intended to add something new.

Gerrity introduced the concept of descriptive and prescriptive mapping of a decision process in DSS development.[16] The descriptive map identifies how the task is currently handled; our focus on user verbs is one approach to doing so. The prescriptive map provides a long-term direction for improving the process. It reflects a normative concept, often derived from theory and research.

Keen and Clark had identified as major shortcomings in existing policy analysis a lack of any real focus on strategic issues, long-term forecasting and conceptual models.[17] Berne's research on equity measures was too far from most analysts' experience and interests for them to apply it. By embedding the easy-to-use EQUITY command in ISSPA, we could encourage them to adopt a broader approach to policy issues. We explicitly viewed ISSPA as a way of bringing policy research to policy making.

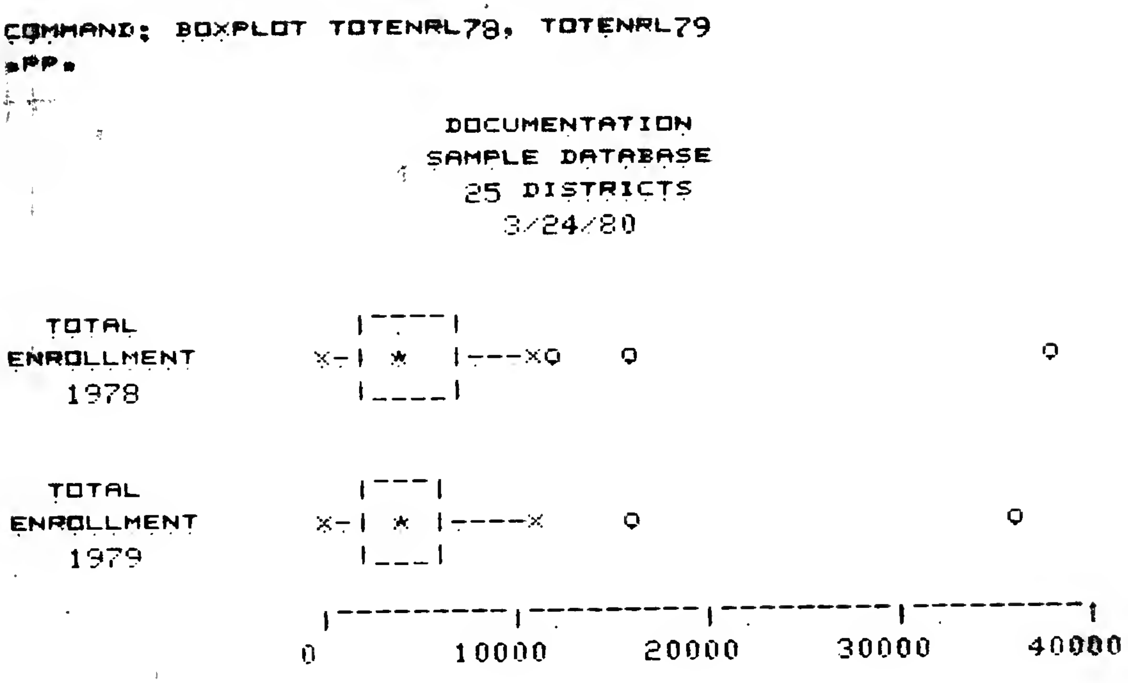
We did not force analysts to use EQUITY. It is one of many resources available in the DSS. Since it involves typing a single phrase, there is minimal effort involved in trying it out. Keen argues that a DSS is often a way of making useful models usable.[18] We took Berne's 12 measures -- the useful component -- and made them accessible. Once we had a complete and stable system, more and more of our effort went into commands like EQUITY which extend rather than support the user. Figure 6 shows three commands, BOXPLOT, STEM and LEAF and CONDENSE, taken from Tukey's Exploratory Data Analysis (EDA).[19] They required very little programming effort[20] and some of our users are unaware they exist; they are an unobtrusive method for stimulating learning. Rule 7 stated: support first, extend later. For a DSS to be more than a convenience, it obviously must go beyond LIST, RANK, DESCRIBE, etc. At the same time, unfamiliar concepts and routines must be presented in a simple way. We did not define an EQUITY model or an EDA package. The verb-based architecture provided an easy bridge between usefulness and usability.

4.6 Phase 3: Building a System Product

Phase 3 involved converting ISSPA from a system to a product. Users were now buying a DSS. We had to provide technical support, documentation and training. Increasingly, we were concerned with costs. APL programs are not inexpensive to run. We had expected ISSPA to cost $50 an hour on the excellent system we were using. The actual figure was closer to $200 an hour. We found that APL penalizes careless programming very heavily indeed. Unfortunately, however, whenever we improved the efficiency of the programs, users were able to do more work in a given time, so that our cost per hour increased. We hired a group of APL

FIGURE 6: EDA COMMANDS

1. BOXPLOT; displays distribution of values for variable(s)



```
COMMAND: BOXPLOT TOTENRL78, TOTENRL79
*PP*

                            DOCUMENTATION
                           SAMPLE DATABASE
                             25 DISTRICTS
                               3/24/80

  TOTAL              |-----|
ENROLLMENT         X-|  *  |---XO     O                       O
   1978              |_____|

  TOTAL              |---|
ENROLLMENT         X-|  * |----X      O                     O
   1979              |___|

                   |---------|---------|---------|---------|
                   0       10000     20000     30000     40000
```

* = median

box shows lower and upper quartiles

---- = interquartile distance

x = lowest and highest data values falling within line which is same length as the interquartile distance extended from lower and upper quartiles

0 = values outside the above range

⊕ = values falling more than 1.5 interquartile distances from lower and upper quartiles

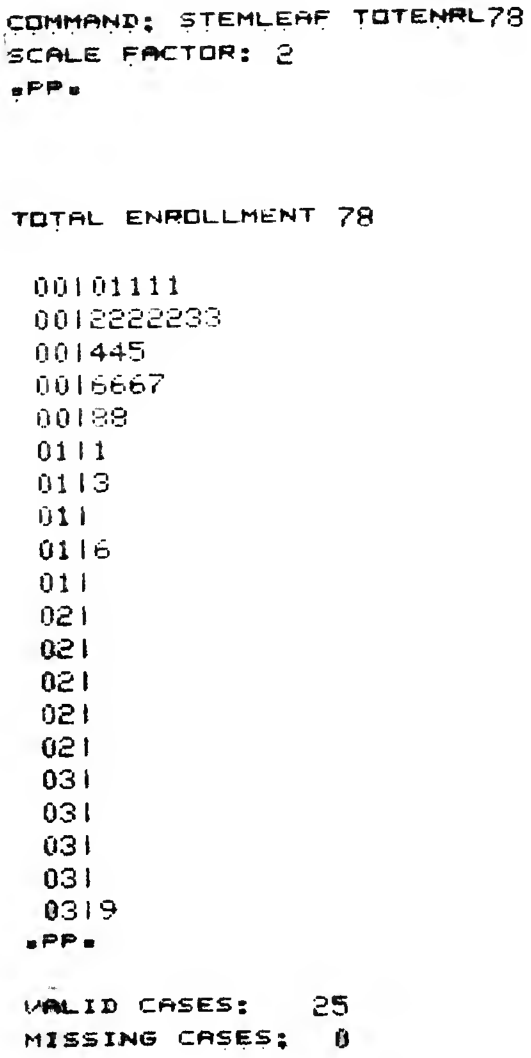
2. STEMLEAF: stem-and-leaf plot

(1) divides range of data into intervals of fixed length (a scale factor may be specified)

(2) stem is vertical line, with interval boundary (0-3) shown to left

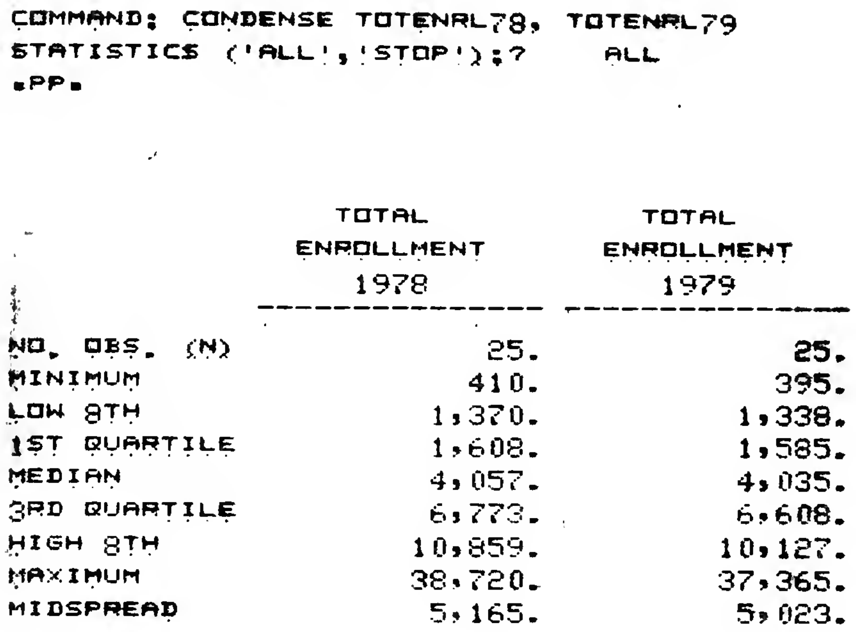
(3) leaf is second significant digit of data value e.g., enrollment of 13,000 has stem of 1 and leaf of 3, 2,000 has stem of 0 and leaf of 2

(4) leaves are sorted and shown in ascending order



```
COMMAND: STEMLEAF TOTENRL78
SCALE FACTOR: 2
*PP*


TOTAL ENROLLMENT 78

 00|01111
 00|2222233
 00|445
 00|6667
 00|88
 01|1
 01|3
 01|
 01|6
 01|
 02|
 02|
 02|
 02|
 02|
 03|
 03|
 03|
 03|
 03|9
*PP*

VALID CASES:    25
MISSING CASES:   0
```

(3) CONDENSE: summarizes distribution of values



```
COMMAND: CONDENSE TOTENRL78, TOTENRL79
STATISTICS ('ALL','STOP');?     ALL
.PP.


                          TOTAL              TOTAL
                        ENROLLMENT         ENROLLMENT
                           1978               1979
                      ---------------    ---------------

NO. OBS. (N)                     25.                25.
MINIMUM                         410.               395.
LOW 8TH                       1,370.             1,338.
1ST QUARTILE                  1,608.             1,585.
MEDIAN                        4,057.             4,035.
3RD QUARTILE                  6,773.             6,608.
HIGH 8TH                     10,859.            10,127.
MAXIMUM                      38,720.            37,365.
MIDSPREAD                     5,165.             5,023.
```

See Tukey, J. Exploratory Data Analysis, Addison-Wesley, 1977, for a discussion of the use of these techniques McNeil provides APL and FORTRAN routines for EDA. The ISSPA routines do not use his code. Outputs from McNeil's version of CONDENSE is shown below.

(McNeil, D. R., Interactive Data Analysis
(Wiley-Interscience, 1977))

experts who were sure they could halve the cost per hour. They were unable to do so. From this, we could conclude that with APL, the code gives little idea of the run time.

Efforts to use desk tops and minicomputers to reduce cost were amusing but ineffectual. With an IBM 5100, run time went from seconds to hours. Even with an HP-3000, we reduced costs by a factor of five and increased response time by twenty. Every improvement in the cost effectiveness of hardware improves DSS capability. However, current technology is still inadequate in providing fast and cheap and easily developed and flexible systems.

Whereas in Phase 1 we were concerned with the process of developing a DSS, in Phase 3 we had to shift our attention to the system product. The transition is expensive. Over a four month period, we added few new user commands but spent almost 800 hours on programming. The effort went into:

(1) improved data management routines;

(2) overlaying functions to reduce cost;

(3) user-system commands, such as:

 (a) SESSION COST: How much have I spent so far?

 (b) WHAT IS Vxxx: What is the label for V?

(4) new commands demanded and often defined by users; it is worth noting that in most cases, the commands represented new ideas and approaches stimulated by ISSPA; and

(5) user documentation, including a comprehensive manual.

As we expected, data and data management became a key issue. Policy analysis generally involves both operational data, such as historical figures on expenditures, program levels and budgets, and planning data, which is often not available from routine sources. We deliberately limited the data management capabilities in ISSPA and required users to provide us with a single tape containing "clean" data. This in effect provided a barrier to entry; if a state lacks capability in data collection or if reliable, current historical data are not available, it makes no sense to provide an interactive DSS to process bad data more quickly and in more detail. McCoubrey and Sulg provided us with a useful decision rule: "Assume the data do not exist, no matter what Data Processing tells you.".

Creating an ISSPA database is technically very simple. Even so, we encountered a variety of irritating minor problems, many procedural. Even with operational data pulled directly off computer tapes, there is some manual link needed. We had to provide a variety of facilities for error checking, and for updating, correcting and adding to the database. Obviously, a generalized database management system would have helped, especially by reducing the manual work required. However, it was, and still is, an infeasible option. DBMS requires a maturation in the use of computers, financial investment and level of technical competence that state governments (and, in our experience, many mid-sized private businesses) lack.

We found that most of the complicated programming for ISSPA went into minor functions for data management. Moreover, we were unable to provide the same responsive service to users in this area that we boasted of in anything involving ISSPA commands. If a user wanted a special analytic routine, we could provide it overnight. Whenever there were problems with a command, the difficulty was invariably easy to resolve, since it was localized. A disadvantage of having data management be "transparent" to the users was that when an error occurred, they had no idea what was going on -- and at times, neither did we. (Transparent means that users are kept unaware of the dynamics or complexity of the system operations; everything "happens" without effort on their part.) The error often affected several user commands.

We found no guidance in the DSS literature, which provides little discussion of data management. None of our problems were complex or hard to resolve, but we found, increasingly:

(a) Programming effort was diverted from user commands to system functions;

(b) processing time and inefficiencies increased as we tackled data management issues; for example, we often had several duplicate copies of matrices to keep track of in the workspace; and

(c) our simple data structure in matrix form (from the user's view) and vector form (the physical structure) was still the best solution. The dilemma for DSS design is that since uses are varied and unpredictable (Section 5), there is no optimal physical or logical structure. Complex data management procedures greatly add to system overhead.

The whole issue of data management in DSS is a complex one, and we could find little help that translated into reliable rules of thumb. Carlsen describes a methodology for data extraction that is powerful but expensive.[21] In general, techniques for ad hoc modeling are far ahead of those for ad hoc data management, especially with large data bases. In Gerrity's PMS and GADS, a DSS developed at the IBM Research Laboratory,[22] most of the programming effort and computing resource was needed for data extraction: pulling from a large permanent database the relatively small subset of variables needed for a given user command. We could not have afforded such overhead; the price we paid was an imbalance between the responsiveness, low cost and flexibility of our analytic commands and the limited, slightly cumbersome nature of our data management routines.

Rule 12: Recognize that data management, not commands (or models) are binding constraint on DSS development:

(a) choose as simple a representation as possible (e.g., a matrix); and

(b) avoid complex data extraction and manipulation.

4.7 Conclusion

ISSPA is now (early 1980) a commercial product. It has to compete in a market that is very cost conscious. Users also expect instant service. Whereas at the end of Phase 1, we were ready to write a paper on the mythical man-month defeated, now we are not so sure. APL, and the middle-out strategy and a command-driven architecture provide immensely powerful techniques for developing a DSS. However, extending a working system to a system product is a complex process, with many hidden costs. For example, there is no quick or cheap way to produce a good user manual. In Phase 1, we were able to "sell" the system through explanation and hands-on experiment, because we were personally credible with our users. By Phase 3, the manual was needed to establish the credibility of ISSPA.

Figure 7 lists our 12 rules of thumb, with two more added:

FIGURE 7: RULES OF THUMB FOR BUILDING DSS

RULE

1. Design the dialog first:

   - define what user says and sees
   - define representation of data

2. Identify user's special-purpose verbs

3. Identify generic verbs relevant to this DSS

4. Translate verbs into commands, and vice versa

5. Check public libraries for off-the-shelf routines

6. Set priorities for implementing commands for Version 0

7. Support first, extend later

8. Evolve complex DSS out of simple components

9. Deliver Version 0 quickly and cheaply

10. Make sure Version 0 sells itself

11. Pick a good user:

    - has substantial knowledge of task
    - has intellectual drive and curiosity
    - will take initiative in testing and evolving Version 0
    - enjoys being innovator

12. Recognize data management is main constraint, not commands

13. Remember Brooks is right

    - programming is 10% of effort

14. Know your user at all times

Rule 13: Remember Brooks is right.

Rule 14: Know your user at all times.

Rule 13 may be restated in several ways:

(1) programming is 10% of the effort;

(2) if you want to build a product that will stand by itself, recognize the time and effort needed; and

(3) Version 0 can be built in weeks.

Rule 14 reflects the whole logic of adaptive design. Of all techniques for applying computer-based models and information systems to complex decision processes, Decision Support involves the most attention to the user as a real person. At every single step in the development of ISSPA, our success depended on:

(1) supporting a person, not solving a problem or building a model;

(2) getting feedback from analysts' direct use of the DSS; and

(3) responding to users' ideas and requests.

5. Principles of Adaptive Design

5.1 Introduction

A recurrent theme in DSS research is user learning.[23] A DSS does not solve problems, but lets individuals exploit their own skills in problem-solving. The obvious strategy for DSS design is to support first, extend later; the initial system is close enough, in terms of commands and mode of dialog, to the users' current procedures to be both attractive and easy to use. Clearly, however, if the DSS is to stimulate changes in the decision process, learning has to occur.

Keen (1979) draws attention to a consistent finding in DSS case studies: the unpredictability of system uses. The actual uses of a DSS are frequently entirely different from the intended ones. For example, Gerrity's Portfolio Management System, intended to support the investment decision, became instead a valuable aid to marketing and communicating with customers. Often, the most innovative and valued uses of a DSS could not have been anticipated by the designer.

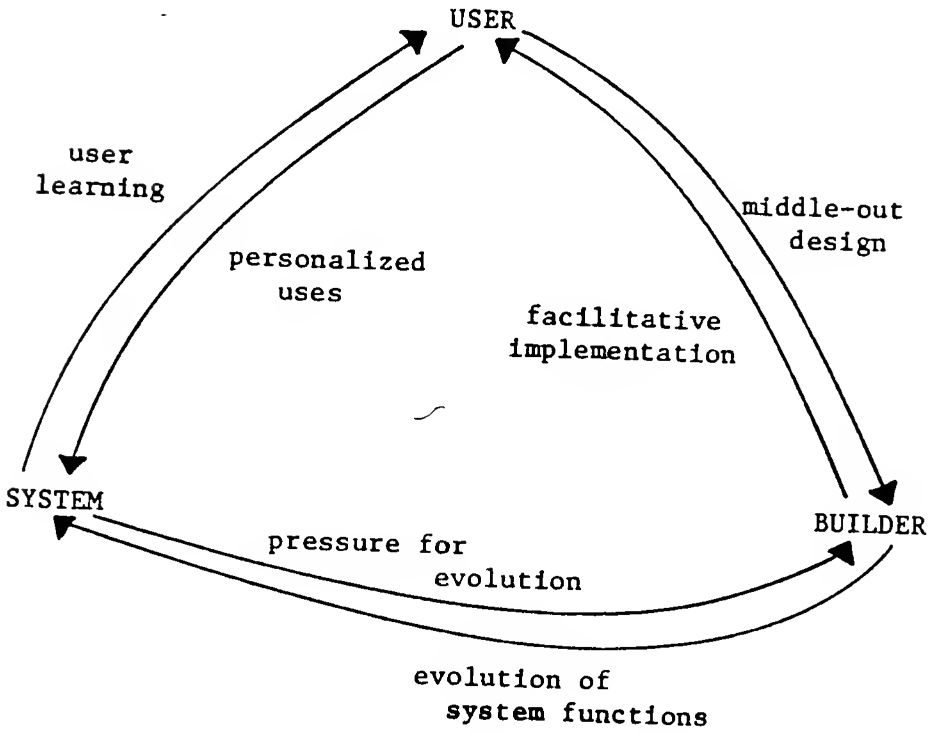
Keen summarizes this process, which has substantial implications for the choice of a design architecture and an implementation strategy, in a framework that views -- in fact defines -- a Decision Support System as an adaptive development strategy applicable only to situations where the "final" system cannot be predefined, but must evolve through the interactions of user, system and designer. Figure 8 shows these adaptive influences.

This conceptual framework was developed partly from a review of DSS research and case studies and partly through the process of developing ISSPA. It translates into some very specific design criteria and techniques. Most importantly, it views user learning as a direct outcome of DSS usage and a contributor to it. The explicit reason for building ISSPA was to help improve policy analysis; learning was viewed as the central issue for design and usage.

5.2 The Cognitive Loop

Each arrow in Figure 8 indicates an adaptive influence. System → User, for example, indicates that the DSS stimulates changes in the user's problem-solving process. If an interactive system does not require or aim at such user learning, then the label DSS is superfluous. Keen argues that it is meaningful to label a system a DSS only if doing so leads to a different development strategy than would otherwise have been chosen.

FIGURE 8: AN ADAPTIVE DESIGN FRAMEWORK FOR DSS



Situations where a system cannot be predefined and used independent of the choices and judgments of the user, and where it will be extended and modified, require a distinctive development process in which learning, adaptation and evolution are central.

The interactions between the user and the system directly relate to learning. The DSS is intended to stimulate changes in user thinking: at the same time, it must be flexible enough to adapt to the user as these changes occur. New tools must shape new uses, and vice-versa. As the user develops a new approach to problem-solving, he or she must not be constrained by the previous one. If a system follows a rigid sequence of routines, learning is blocked. The User → System link thus relies on a design architecture that permits personalized use; without it, any learning stimulated by the DSS cannot be exploited.

5.3 The Implementation Loop

Keen terms the user-system links, the cognitive loop. The implementation loop refers to the relationship between the designer and the user.

Ness defined a key aspect of adaptive design: "middle-out" development.[24] This is contrasted with top-down or bottom-up approaches, and relies heavily on fast development and prototyping. Middle-out design provides a means for the designer to learn from the user (User → Designer). While the concept of adaptive design is somewhat broader than middle-out, Ness's concepts are at its core.

The implementation process requires a facilitative strategy on the part of the designer (Designer → User). A DSS is not an off-the-shelf product. Building it requires close involvement with the user. Several researchers have commented on the need for an intermediary (Keen) or integrating agent (Bennett) who can act as a crusader, teacher and even confidant.[25] Adaptive design is a joint venture between user and designer. Each needs to respect and understand the other. The designer's job goes well beyond traditional systems analysis and functional specifications. He or she needs to:

(1) understand the task and user;

(2) be able to humanize and even customize the system; and

(3) be responsive to the user and help stimulate exploration and learning.

In most instances of successful DSS development, the system is associated with a skilled intermediary/implementer. The DSS is as much a service as a product.

5.4 The Evolution Loop

The evolution loop relates to the process by which learning, personalized use, middle-out and facilitative implementation combine to make the initial system obsolescent and evolution essential. This is shown in Figure 8 as an adaptive link from system to designer. Evolving the system means adding new commands (Designer → System). Knowing when and how to evolve it requires keeping track of user and usage (System → Designer).

The main value of the command-based architecture used in ISSPA is that it is easy to add commands, given APL. The DSS designer has to plan for evolution. Since many of the new commands will be user-defined, they may be very different from the preceding ones. Obviously, however complex or esoteric they may be, it is essential that they do not involve restructuring the program, only adding independent modules to it. Brooks describes the need for "conceptual integrity" in the architecture of a system:

> "The purpose of a programming system is to make a computer easy to use .... Because ease of use is the purpose, (the) ratio of function to conceptual complexity is the ultimate test of good system design ....
>
> For a given level of function, however, that system is best in which one can specify things with the most simplicity and straightforwardness."[26]

Evolving a DSS relies on conceptual integrity. The command-based, top-down structure of ISSPA provides for this. A major postulate of the adaptive design framework is that a DSS is a vehicle for user learning and hence, that evolution is inevitable and essential.

Knowing when and how to evolve the DSS is often difficult. In the initial stages of development, there is usually close and direct contact between Designer and User. Later, however, the designer will need a more formal methodology for tracking usage. The obvious one is a data trap which records, with users' permission, each command they invoke. These records may be analyzed in terms of mode of use, reliance on individual commands, and stringing commands together into distinct sequences or sentences. A data trap can provide a wealth of information to the designer. However, there is no easy way of interpreting it. (Stabell, Andreoli and Steadman provide one approach, used to evaluate Gerrity's Portfolio Management System.)[27]

5.5 Adaptive Design in ISSPA

The descriptive mapping of the ISSPA users' decision process was done by Keen and Clark, with a view towards defining ways to improve analytic capability in school finance policy analysis.[28] It was clear that analysts most want, and know how to use, simple, reliable data.

Whereas in statistical analysis they focus on medians, averages and correlations, they are also concerned with measures of range and variance, and with outliers. For example, they often need to look at extremes, such as the lowest and highest 10% of districts in terms of tax revenues per pupil. Their role is frequently to explain issues to legislators, and respond very quickly to their requests for analysis.

The descriptive mapping identifies the key issues in making a DSS *usable*. The prescriptive map defines how to make it more *useful*. Our analysis was similar to Gerrity's and Stabell's assessment of the Portfolio Management System. We found that the analysts had fairly simple concepts of policy analysis and relied on only a few techniques, especially ranking and linear regression. The descriptive map for a DSS focusses on how people carry out a task. The prescriptive map looks at the task itself. Gerrity found a lack of analytic concepts among portfolio managers. There is a rich body of financial theory relevant to their job that they do not draw on. They do not base their decisions on analysis of their customers' portfolios, but think in terms of individual stocks, ignoring issues of risk-return trade-offs. The school finance analysts similarly ignore policy research; they think incrementally and rarely go beyond the discussion of the bottom line. They focus on very few overall policy issues.

Gerrity built PMS to support the existing process and move users towards a more analytic one. Stabell found that the intended change did not occur and argued that not enough attention was paid to *how* to stimulate learning. With ISSPS, we intended to evolve the system by adding commands that reflected concepts new to the analysts. For example, we hoped to introduce adaptive forecasting techniques, incorporate research on equity measures and encourage sensitivity analysis and exploratory data analysis. Clearly, it is unlikely that analysts subject to organizational traditions and pressures of day-to-day operations, will spontaneously adopt these new approaches. We needed some leverage point and decided that the key issue for stimulating learning is to find a really good user. Our assumption, backed up by the findings from DSS case studies is that skilled users, helped perhaps by capable intermediaries (Designer → User in Figure 8), will explore the DSS, find personal ways of using it (User → System), provide the design team with insights and challenges (User → Designer) and respond to recommendations and training (Designer → User). In this way, they themselves will help the system evolve.

We viewed ISSPA specifically as a vehicle for stimulating user learning. We expected that:

(a) initially users would rely on fairly simple commands, reflecting simple user verbs;

(b) as they got used to the DSS and found it valuable, they would string these together into sentences, reflecting a methodology for analysis; once this occurred, we would need to provide an "exec" facility; and

(c) they would then ask for extensions to existing commands, define new ones and be ready to try out ones such as EQUITY.

The principles of adaptive design indicated that for this sequence to occur (as it did), we had to ensure that the development process allowed all the adaptive links to operate:

(1) for the cognitive loop, this meant:

(a) the interface and dialog must be communicative, responsive and easy to use and the commands directly relevant to the existing process, to facilitate use and learning (System → User). (We have no formal measures of the quality of these features of the interface; the number of user errors, as revealed by the data trap, and user comments are reasonably adequate indicators.); and

(b) the DSS be command-based, with minimal constrictions on mode and sequence of use, to allow personalized, innovative use (User → System)

(2) for the implementation loop:

(a) middle-out design, relying on APL to permit responsive service (User → Designer); and

(b) close contact with users, either by one of the development teams or a technical intermediary with good knowledge of school finance, from within the user organization (Designer → User)

(3) for the evolution loop:

(a) a data "trap" to monitor how individual users work with ISSPA; and

(b) ongoing addition of new commands, expecially in response to user requests and ideas (Designer → System); this also requires continued research on our part.

The weakest aspect of our efforts to apply this adaptive development strategy was in the implementation loop. We frequently did not provide adequate facilitation (Designer → User). Users need "hand-holding" not because they are stupid or scared of the system, but because the adaptive links, especially the cognitive loop, <u>consistantly strain the existing system</u>. There is a continuous state of flux. Users who have had no trouble for months may move to more complex analysis, using the same commands, or want to try new ones. The designer has to remain in the loop and the middle-out process has to continue. We frequently got phone calls from users, trying to tell us what they needed and asking for very small adjustments to the DSS. Failure to respond in such situations blocks learning or interrupts the users' efforts to adapt the system to their own problem-solving.

We found that personalized usage is, as we expected, the rule and not the exception. Every ISSPA user has an individual style. Some are very visual and rely on graphics rather than tables, and some continuously define new variables (e.g., (V101 + V207)/V371 = "number of special education students per full-time teacher"). Some use ISSPA as a report generator, others as a means of model-building. Some are systematic and others more divergent in their problem-solving. Almost invariably, dissatisfactions with ISSPA comes from a user's need for an individualized system.

The good users quickly identified new commands they wanted. These could not have been defined in advance. We spent substantial time when the initial version was released getting a "wish list" from the first users. However, it was the actual use of the DSS that stimulated demands and specifications.

The success of ISSPA has depended on supporting the cognitive loop and evolving the DSS. We anticipated this and conclude that DSS designers should, as we did:

(1) design the dialog first and ensure it provides an immediately usable, flexible and responsive system;

(2) think in terms of verbs and commands; and

(3) present users with a simple, clear data representation.

6. Command-Based DSS and User Verbs

The second point above is contentious and conflicts with the recommendations of several DSS researchers. Bennett, for example, demonstrates the value of a menu-driven approach for interactive graphics.[29] It is easier for users to be reminded of what they can choose than to have to specify it. A menu design minimizes the need for prior knowledge and provides familiar and recognizable options. Artman shows how a DSS architecture can combine the merits of the menu representation and command flexibility, using an APL-based menu generator developed by Sigle and Howland.[30]

Our choice of command-driven system was based on both behavioral and technical considerations:

(1) Given our concern for stimulating learning and, hence, the use of new analytic methods, we wanted the design structure to be directly related to the users' way of thinking.

(2) If the DSS is a collection of discrete, independent functions, APL can be used to great advantage.

A new function in ISSPA is defined by the user in terms of:

VERB: NOUN(S): MODIFIER.

For example, RANK V401, V509 by V101. The verbs are APL functions and the nouns are data items. There is a minimal amount of translation from the user's concept to the technical implementation. Users understand the idea of commands; their specification is bounded by the use of the verb, even though they may not define exact calculations and output formats.

This approach is ideally suited to middle-out design. The designer and user sketch out the dialog and the designer produces a first cut that can be quickly modified in response to the user's reactions.

The modifier is, conceptually, an adverb. ISSPA is command-based. Within a command, we use a structured dialog or menu to handle sub-options. The initial version of CORRELATE thus asked:

DO YOU WANT PARTIAL CORRELATIONS?

WHICH VARIABLE DO YOU WANT TO CONTROL FOR?

Our ideas on verbs and commands were influenced by Blanning and Contreras.[31] Blanning takes a linguistic approach to DSS design and aims towards a generative grammar. Contreras, following Berry, shows how APL allows levels of language that permit a rich English-like dialog to be built up from very simple building blocks.[32] Keen and Wagner describe IFPS, a FORTRAN-based end-user planning language, well-suited to DSS development.[33] IFPS is not command-based, but reflects the same focus on specifications being given to the system via a simple syntax based on command/verb, nouns and adverbs, that corresponds to something in the user's head. Examples are:

(a) Contreras and Skertchly:[34]

```
DEFINE 'RESULTS' AS (PRICE x SALES) - (COST x INVENTORY)
                  COMPUTE RESULTS
                DISPLAY MEDIAN PROFIT
           COUNT DEMAND > AVERAGE DEMAND.
```

DEFINE, AVERAGE, COMPUTE, DISPLAY and MEDIAN are APL functions.

(b) IFPS:

```
                  COLUMNS 4
    SALES 109, 115, 1.03 * PREVIOUS SALES
                      .
                      .
                      .
                      .
 WHAT IF SALES 110, 116, 1.05* PREVIOUS SALES
```

(c) ISSPA:

DESCRIBE TOTENRL78; AVERAGE; MEDIAN; STOP[35]

DISPLAY V101 FOR DISTRICTS

SELECTIF COUNTY = 2

The ISSPA "sentences" are less rich than the others. However, this building-block approach is easily extended. The initial version of ISSPA was a simple set of commands. Noise words (AND) and adverbial modifiers were added, e.g., CROSSTAB ... BY, DISPLAY ... PER. More recently, Gambino has extended the command syntax and developed an ISSPA planning language, which provides a model-building capability (Figure 9). Interactive Modelling and Planning System (IMPS) has grown directly out of ISSPA. This suggests that a DSS for learning and adaptive development is in effect an end-user language and that the verb-based structure is an elementary pidgin-English. Blanning's richer linguistic formalization and Contreras' use of APL are a natural extension of our more simple approach.

Each ISSPA command is a single "do something to something". In several instances, we later broke a command into two; CORRELATE originally included full and partial correlations. This is really two separate "do somethings". The dialog was clumsy and much of it redundant. It was easy to change the code. The main reason for the original design was that the function was taken directly from a public library. We have consistently found that APL programmers -- perhaps most programmers -- seem to pay very little attention to the connection between the user's way of thinking and the program. The dialog is often cumbersome and output formats visually cluttered and hard to follow. In integrating any function from a public library into ISSPA, we generally have to do very little to the logic, but must tidy up the dialog.

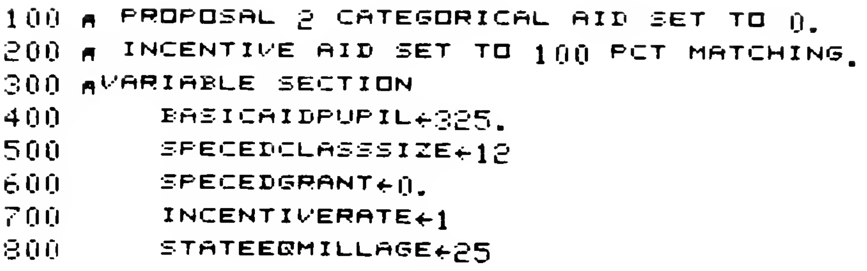
FIGURE 9: IMPS (INTERACTIVE MODELING AND PLANNING SYSTEM)

IMPS creates a file of inputs to an ISSPA run and APL statements. This permits:

(1) Simulations to be created, quickly. (IMPS was used in one state to build a generalized school finance model in about a week.)

(2) ISSPA commands to be strung together into "exec" files; in the example below, line 1100 generates the asterisked user inputs and sequence of ISSPA commands.

1. IMPS Code



```
100 ⍝ PROPOSAL 2 CATEGORICAL AID SET TO 0.
200 ⍝ INCENTIVE AID SET TO 100 PCT MATCHING.
300 ⍝VARIABLE SECTION
400      BASICAIDPUPIL←325.
500      SPECEDCLASSSIZE←12
600      SPECEDGRANT←0.
700      INCENTIVERATE←1
800      STATEEQMILLAGE←25
```

100-300
Comment lines

400-800

APL statements creating non-ISSPA variables which are needed in a simulation capability

```
 900 ⍝EQUATION SECTION
 1000 CLEAR
1100 CHOOSE:I;V102;V104;V504:V506;STOP
1200 ⍝COMPUTE STATE BASIC AID
1300 DEFINE TOTADM78×BASICAIDPUPIL
1400 STATE BASIC AID PROPOSAL 2
1500 BASICP2
1600 STATE BASIC/AID/PROPOSAL 2
1700 F15.2
1800 ⍝COMPUTE CATEGORICAL AID (SPECIAL ED.)
1900 DEFINE SPECEDGRANT×(0⌈SPECEDADM78÷SPECEDCLASSSIZE)
2000 CATEGORICAL AID PROPOSAL 2
 2100 CATEGORICALP2
2200 CATEGORICAL/AID/PROPOSAL 2
2300 F15.2
 2400 ⍝COMPUTE INCENTIVE AID
2500 DEFINE INCENTIVERATE×(.001×0⌈V504-STATEEQMILLAGE)×V506
2600 STATE INCENTIVE AID PROPOSAL 2
2700 INCENTIVEP2
2800 INCENTIVE/AID/PROPOSAL 2
2900 F15.2
3000 ⍝COMPUTE TOTAL STATE AID UNDER PROPOSAL
3100 DEFINE BASICP2 + CATEGORICALP2 + INCENTIVEP2
3200 TOTAL STATE AID UNDER PROPOSAL 2
 3300 TOTAIDP2
3400 TOTAL STATE/AID/PROPOSAL 2
3500 F15.2
3600 ⍝DISPLAY SECTION
3700 DISPLAY BASICP2,CATEGORICALP2,INCENTIVEP2 FOR DISTRICTS
3800 ⋆SAMPLE
3900 STOP
```

1000-3900 ISSPA
command sequence

1000 clear all current
active variables

2. Part of the IMPS Run

```
* COMMAND:  CLEAR                                                    (line 1000)

* COMMAND:  CHOOSE                                                   (line 1100)

*  GROUP OR ITEM?  I

*  ENTER VARIABLE TO BE CHOSEN ('STOP) V102
*                                      V104
*                                      V504
*                                      V506
*                                      STOP

COMMAND: *COMPUTE STATE BASIC AID                                    (line 1200)
                                                               (lines 1300 - 1700)
COMMAND: DEFINE TOTADM78×BASICAIDPUPIL

ENTER IDENTIFIER: STATE BASIC AID PROPOSAL 2

ENTER SYNONYM (ONE WORD--NO BLANKS): BASICP2

ENTER PRINT LABEL: STATE BASIC/AID/PROPOSAL 2

ENTER FORMAT CODE: F15.2
                                                         (run for lines 1800 -
                                                         3500 omitted here)
                  .
                  .
                  .
                  .
                  .

COMMAND: *DISPLAY SECTION                                            (line 3600)

COMMAND: DISPLAY BASICP2,CATEGORICALP2,INCENTIVEP2 FOR DISTRICTS         (3700)
DISTRICT (STOP):    *SAMPLE                                               (3800)
DISTRICT (STOP):    STOP                                                  (3900)
OFF.
```

```
                                      STATE BASIC       CATEGORICAL        INCENTIVE
                                          AID               AID               AID
                                       PROPOSAL 2        PROPOSAL 2        PROPOSAL 2
                                     --------------  ----------------  ----------------

  1. 0102 BEACHWOOD CITY S.D.            522,925.00              0.00      3,584,331.50
  2. 0301 BIG CITY S.D.               35,874,475.00              0.00     62,380,435.72
  3. 0501 CAPITOL CITY S.D.           28,269,962.50              0.00     15,687,347.47
  4. 0504GRANDVIEW HEIGHTS               456,950.00              0.00        672,362.03
  5. 0401 HUNTINGTON LOCAL S.D           406,006.25              0.00         35,944.39
  6. 0403 MIAMI EAST LOCAL S.D           526,743.75              0.00        227,183.52
  7. 0106 MONROEVILLE LOCAL              253,012.50              0.00        391,538.87
  8. 0207 WINDHAM EX VILL S.D.           512,443.75              0.00        311,104.92
  9. 0206 XENIA CITY S.D.              2,201,550.00              0.00      1,282,141.51
SIM*
```

A useful additional benefit of a command-based design is that one may disguise the DSS. We can make ISSPA look like a simple reporting system by not informing users that commands such as REGRESS, CROSSTABS and EQUITY exist. Similarly, we can present it as a statistical package. More importantly, we can hide and later reveal commands. For example, we designed several simple functions for exploratory data analysis (Tukey). They can be incorporated into the system and brought to the attention of individual users when the time seems right. A command becomes apparent only when it is used. Already, we have developed commands specifically for an individual user. These are part of ISSPA but not revealed to all users.

The commands relate to learning and evolution. The adaptive development strategy also implies a level of representation of user behavior, design criteria and system functions. We need a common and comparable methodology for:

(1) descriptive mapping: at a global level, one could capture users' problem-solving in terms of, say cognitive style (McKenney & Keen, Henderson)[36] or at a micro-level in terms of uses of visual images. Neither level of analysis, however, provides clear design criteria for a DSS.

(2) prescriptive mapping: here again, one might define an optimal decision process in terms of an overall logic (e.g., decision theory, linear programming) or, at the micro-level, in relation to individual decision rules. There is no link in either case with the descriptive map.

(3) DSS design structure: a macro-level representation is a set of program (or model) specifications, and the micro-level, the program logic. There is no link here with the maps of the task and user processes.

An intermediate level permits comparability and integration. User verbs, correspond to subtasks and translate into commands. Figure 10 extends the adaptive design framework to include task representation. Adaptive design involves describing decision processes in terms of verbs, tracking user learning in relation to the use of commands and the verbs they reflect (and vice versa), and evolving new commands. Learning can really only be monitored in relation to the concrete evidence provided by the data trap.

The command-verb link is thus the means by which an understanding of the decision situation is translated into system functions and their use observed in order to extend the DSS. We find the use of command-verb as the discrete unit of analysis and design to be convenient, reliable and informative.

We are currently analyzing longitudinal data collected by the data trap. Essentially, this involves a form of protocol analysis. The data support our initial expectations that:

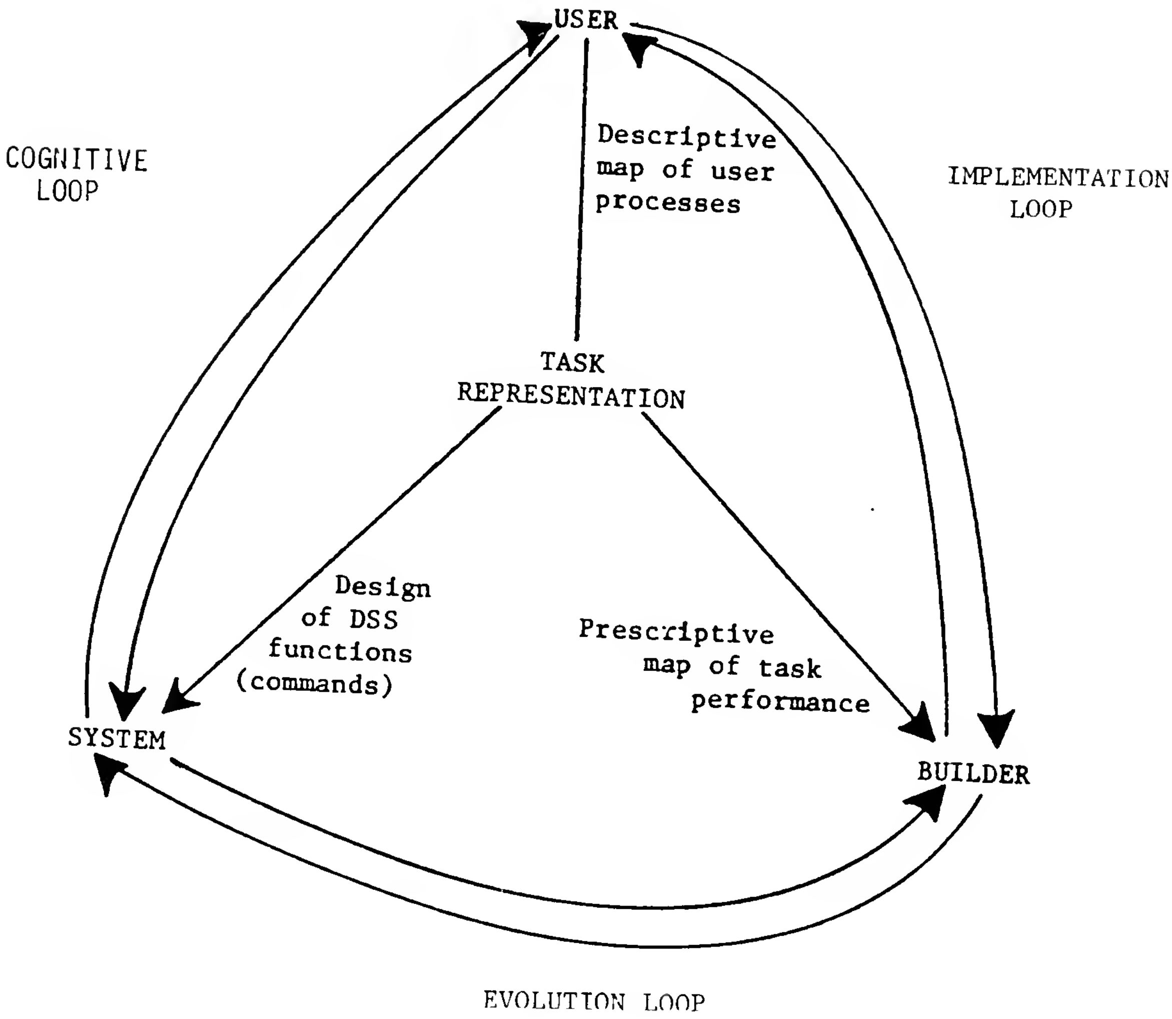
(1) Usage of ISSPA will be personalized; there is no overall pattern across users;

(2) Each user will develop consistent command sequences, for a given task. A sequence might be, for regression analysis:

(a) SCATTER, get a scatter diagram;

(b) CORRELATE;

FIGURE 10: TASK REPRESENTATION IN ADAPTIVE DESIGN


USER
COGNITIVE LOOP
Descriptive map of user processes
IMPLEMENTATION LOOP
TASK REPRESENTATION
Design of DSS functions (commands)
Prescriptive map of task performance
SYSTEM
BUILDER
EVOLUTION LOOP

(c) REGRESS;

(d) DESCRIBE residuals.

This sequence reflects a coherent approach to analysis, largely stimulated by the DSS.

(3) The scope of analysis will be broadened; this is indicated by the use of the more "prescriptive" commands, manipulation of variables and idiosyncratic sequences reflecting a concept, heuristic or personal strategy.

The data trap records user identification, day, time, and ISSPA command. It is simple and informative. With one user, for instance, we tracked over a two-week period, a shift from correlation analysis and tabular displays with limited manipulation of variables (via the DEFINE command) to:

(1) Examine outliers and divide the distribution into discrete groupings (e.g., deciles).

(2) Analysis of selected districts, grouping districts into categories.

(3) Weighting individual groups, and manipulating the grouped variables.

From both research on DSS and our own experience, we strongly conclude that a command-based strategy is natural for DSS development. It clarifies how to look at the users' process, before and with the DSS, how to design and evolve the system and how to evaluate it. What is missing at present is a clear theory of user learning. There is a gap between the descriptive and prescriptive decision process; bridging it is a rather haphazard process at present.

7. APL and the Mythical Man-Month

The preceding two sections discuss aspects of program design rather than programming. DSS do not involve any distinctive technology; they use FORTRAN, APL, CRT's, standard data management concepts, etc., and are frequently small in scale. They imply, however, a particular programming style. The main reason many DSS designers advocate the use of APL is their concern for:

(1) fast delivery of the system;

(2) the ability to restructure the DSS at short notice;

(3) direct and responsive service to users; and

(4) reducing the fixed costs of program development and making it a marginal cost venture.

The first three of these points follow from the principles of adaptive design. Middle-out, in particular, relies on fast delivery and fast modifications; all momentum and credibility are lost if users have to wait for a month for response. Case studies of DSS (see Keen, Alter)[37] emphasize these issues, particularly the value of having a prototype system being made available at a low cost to demonstrate the feasibility and value of the DSS. Quite often, these prototypes are "bootlegged"; the design team spends one or two weeks rushing to get a system up while management is still discussing the business problem and their options. Low cost is essential in such a situation. Management clearly is unlikely to approve a $50,000 investment to try out the designers' ideas: the prototype is, after all, only a first-cut, a hypothesis and an experiment.

One of the major blockages to the application of computer technology to management decision making over the past decade has surely been the high fixed costs of programming. Data processing departments cannot respond to ad hoc requests for small reports or simple analysis. Any COBOL program is likely to involve a month to write and test, even when the logic is simple. Similarly, changes to an existing program are surprisingly expensive (surprising to the client). Often, they are not even feasible, because they require major changes to the existing program structure.

Adaptive design and evolution are likely to succeed only if DSS development involves low fixed costs. Developing the initial system and adding a new command should require only an incremental investment, where the main cost is the programmer's charge per hour.

The cost function for program development is basically:

$$\text{Cost} = F + (PH \times PR) + (MH \times MR) + (UH \times UR)$$

where:

(1) F is the fixed cost of logic design, housekeeping and system set up (e.g., JCL, ENVIRONMENT DIVISION statements in COBOL); this is basically independent of the application;

(2) PH is number of programmer hours and PR the cost per hour;

(3) MH and MR are the machine hours (for testing and trial use) and cost per hour; and

(4) UH and UR are the users' time and costs.

In traditional data processing applications, F is high, and the costs for machine time and user time relatively low. The programmer cost per hour for COBOL is also low in relation to that for really outstanding programmers working in, say, a marketing staff unit or as consultants. PH is generally high.

The costs are very different in DSS applications. PR will be high since:

(1) middle-out and descriptive and prescriptive mapping require an understanding the decision making context; the designer has to be able to relate well to and interact with relatively senior managers and professionals; the average systems analyst and COBOL programmer lacks the training or interest for this;

(2) if a system is to be built quickly, the programmer has to be far more productive than the average data processing professional; and

(3) the importance of a clear program architecture, flexible structure, functional generality, and responsive interface requires that the programmer have experience with on-line applications, and strong skills in programming techniques. Much of the adaptive development strategy is similar to top-down design, structured programming and stepwise refinement. These tools for improving software productivity are not easy to learn: EDP Analyzer reports that programmers need to be "converted .... and very likely they will resist the new techniques at first".[38]

If PR is high, PH needs to be low. Moreover, DSS development requires users to be directly involved. Grajew and Tolovi found that the number of hours required -- using middle-out -- is not high (less than 50 hours spread over 16 weeks) but whereas "users" in data processing applications are generally junior to middle-level clerical personnel and supervisors, with DSS they are higher-paid managers or professionals, who also have little time available. Reducing PH helps reduce UH.

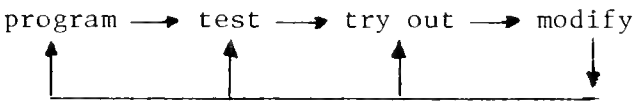
The attractiveness of APL for many designers follows from the trade-offs it allows among components of the cost function. F is negligible, particularly using a command-based structure: in general, one can "bread-board" a system and get started quickly. APL relieves the programmer of set-up charges such as dimensioning arrays, and declaring variable types of data names. PH is dramatically reduced; a given piece of program logic can be coded in about one-tenth of the time required with FORTRAN. With a DSS, much of the existing code at any stage will later be rewritten; this is especially true with the initial version of the system. The language is compact, with one APL line equivalent to 6-15 lines of FORTRAN.

With APL, the cost function becomes:

> a low fixed cost (F) + low programmer hours (PH) x
> high programmer cost per hour + high machine cost +
> relatively high user costs (UH x UR).

If delivery time is a key factor, then obviously users will be ready to pay a premium in terms of PR to reduce PH.

With APL, one must accept relatively high machine costs. Middle-out implies a fairly continuous cycle:



The process is inefficient in terms of machine usage. Machine costs per hour are likely to be high for several reasons:

(1) APL is an interpretive language.

(2) An interactive system must provide good response time; this often is possible only with a high quality, expensive time-shared system, especially if, as with ISSPA, there are operations on large matrices.

(3) A good user can do a great deal of work in an hour with a well-designed DSS.

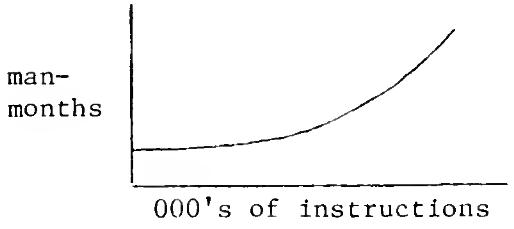
Cheap APL services are available. Too often, however, they are unreliable and overloaded. Cadillac service is not cheap.

It is extremely unlikely that we could have built the initial version of ISSPA without APL. With middle-out design, every day counts. Much of the interaction between designer and user involves trying out ideas at the terminal. In several instances, we responded to a user's request on the spot. For example, one analyst wanted to know if we could provide a PERCENT function. Ten minutes later -- and three lines of APL -- there it was. An interpretive language facilitates such development.

The specter of the mythical man-month loomed over us throughout the development process. Brooks' warning for software designers is:

(1) When the code is written, 10% of the work is done.

(2) As program complexity grows by x, programming effort increases by x^a, where the exponent a is estimated by Nanus and Farr and by Weinwurm[39] to be about 1.5:



(3) Much of the incremental 90% of the effort involves testing and integration.

We believed that using APL would enable us to:

(1) reduce the time needed for the 10%;

(2) borrow from public libraries, thus reducing testing;

(3) break the program up into small, discrete units so that x^a is close to x;

(4) integrate new routines easily; and

(5) reduce program errors.

In general, our expectations were met. We encountered three main types of problems, all of which had a significant impact on development time and costs:

(1) As the <u>use</u> of ISSPA became more complex and new functions were added, interaction errors were introduced; Command A works perfectly, as does Command B, but used in sequence, they generate a bug, often an elusive one.

(2) Far more resources were needed for the user-system dialog than for the logic of the commands.

(3) The initial commands permitted us simple "sentences". Evolution, user learning and the addition of user-defined commands result in -- intendedly so -- more complex ones. It then became essential to introduce consistent system conventions and add system commands. These do not add to the functional capabilities of the system and diverted resources from the evolution of user commands.

(4) Machine costs were far higher than expected and the code was "opaque".

Brooks' response to the first three points might well be, "I told you so.". He did. We thought we could finesse the problems implicit in Figure 1. Almost certainly, we still saved substantial time and effort by using APL but the pattern Brooks identifies seems to hold as much for ISSPA as for data processing projects. Coding is still 10% of the effort.

This point is not discussed much in work on either APL or DSS. Many, perhaps most, model-based DSS described in case studies are either for ad hoc use, in which case there is no need to make them into products, or the work is done by high-quality, low cost programmers working in universities. Clearly, APL is very effective for ad hoc systems.

The interaction errors often related to problems with internal pointers and multiple copies of matrices which are not consistent. As we elaborated the "syntax" of ISSPA, several commands would be used within other commands. To the user, the structure remained simple; indeed, the whole aim in designing the user-system dialog was to ensure ISSPA be easy to use even by someone with no prior experience with computer systems. Internally, however, the structure grew exponentially more complex. This was also true for the data management routines.

The interaction errors were sometimes hard to trace. Errors in the logic of a user command were quickly found. As mentioned earlier, users played a key role in locating unobtrusive errors, ones which the programmer is unlikely to spot. Their expertise in school finance combined with initiative, intelligence, and interest in ISSPA significantly affected the technical quality of the DSS.

While the use of routines from public libraries clearly reduced testing time, since they are already debugged, we had to spend substantial effort in improving the user-system dialog. For example, the FREQUENCIES command took two hours to integrate and check out and almost twenty hours to redesign the dialog. Many programmers seem to have little sense of aesthetics. Figure 11 shows a sample output from an APL-based DSS that the designer regards as easy to use and well-suited to managers' needs. It is fairly typical of the style of most of the routines we took from public libraries, and does not meet the standard of dialog we view as critical for DSS. The output table is not self-explanatory, the abbreviations seem unnecessary (QTY for QUANTITY) and the spacing poor.

Ness argues that a DSS cannot be made more useful by adding "cosmetics".[40] Our view is very different, and seems to be supported by users' reactions. We felt that a DSS has be be seen as a personal tool and a mundane one. "Mundane" is hard to define here: it means easy to live with, quickly integrated into one's ongoing activities and then, in a way, taken for granted. A calculator is personal and mundane in this sense. "Cosmetics" are an important aspect of mundaneness. The quality of the read-out display, the size of the buttons, the location of functions, etc., make a particular calculator easy to live with. An indication of one's satisfaction with it is that it is taken for granted. With some calculators, one's attention is drawn to very minor inconveniences or cosmetic flaws.

We felt, and still do, that for a DSS <u>product</u>, cosmetics are important. The dialog in Figure 11 may be acceptable to a person with a technical bent but not to most others. We went to great lengths to build a mundane system. For example, the DESCRIBE command produces descriptive statistics, including the standard deviation and variance of a variable. If the variance is too large for the output field,

FIGURE 11: EXAMPLE OF APL DIALOG

```
SELECTION:PROD=CHAIR∧CITY=ATL,BOS,CHI
FUNCTION:CROSS
ROW CLASS 1 (OR ROW FIELD):CITY
COL CLASS 1 (OR COL FIELD):QTY≤10
COL CLASS 2:=11_50
COL CLASS 3:>50
COL CLASS 4:
TAB FIELD:PRICE×QTY
PERCENTAGES (Y OR N):Y
PAGE NO. 1

12:35        4/20/77          APL DATA INTERFACE
DEMOSALES VFILE;PROD0='CHAIR'∧PROD1='  '∧CITY=ATL,BOS,CHI ;CROSS·
              TAB:PRICE×QTY

                       QTY
CITY        C1         C2         C3       TOTAL
         → .57      → .43      → .00
ATL       9340       7110          0       16450
         ↓ .35      ↓ .17      ↓ .00     ↓ .17

         → .20      → .57      → .22
BOS       8300      23570       9240       41110
         ↓ .31      ↓ .58      ↓ .35     ↓ .44

         → .24      → .28      → .48
CHI       8810      10250      17500       36560
         ↓ .33      ↓ .25      ↓ .65     ↓ .39

         → .28      → .43      → .28     → 1.00
TOTAL    26450      40930      26740       94120
```

→ = row percentages

↓ = column percentages

initially asterisks were printed. This is a convention familiar to FORTRAN users but makes no sense. The variance is not ***********. While a policy analyst will get used to asterisks appearing on a report, a legislator will wonder why the computer made a mistake. We decided to substitute the words VERY LARGE. Similarly, if the variable has no mode, we printed NONE instead of 0.

In several states, we did not make any presentation of ISSPA to senior administrators in the users' organization. The users did so; it was their system, not ours. They almost invariably emphasized the "cosmetics", which they viewed as a reflection of our willingness to tailor ISSPA to their needs. To an extent, functional capabilities are taken as a given. A calculator multiplies and divides; the issue is how well does it do so, which translates to how "mundane" it is.

In retrospect, we needed to carry the concepts of "verbs" and commands further than we did in the initial design. ISSPA has become in effect an end-user language. It involves a simple grammar, which includes modifiers and conjunctions. The conventions must be consistent and easy to learn. We had minor, but unnecessary problems with prepositions. For example, the CROSSTAB, RANK, EQUITY, NTILES, WAVERAGE (weighted average), and SCATTER commands all require a 'by', 'with', or 'versus'. We initially did not take into account the fact that as commands evolve from simple generic verbs to user-defined routines, prepositions and modifiers become more necessary and frequently used. The surface texture of the dialog has be be graceful, consistent and lucid. This obviously takes careful design; even though the programming is simple, it takes up more time than does coding the user commands.

For similar reasons, we increasingly had to commit resources to developing system commands, which either increased flexibility of the

DSS or provided help and information about ISSPA.

WHAT IS Vxxx

SYNONYM; this allows the user to change a variable label or identifier.

LABEL; for improving readability of reports.

COMMAND COST

SESSION COST

CONTINUE (originally named LUNCH); this allows the user to log-off and restart at the same point.

All these commands were developed in response to user requests or problems. The design structure made it easy to integrate them and they involved small increments of effort. However, at one point, we had to hire a junior programmer to handle them and for some time were not able to keep up with our user's growing demands for such add-on features.

Our initial estimate of the cost to run ISSPA was $40 an hour. We used a high-quality time-sharing service with its own private telecommunications network, which permitted total portability. We could work from Philadelphia with users in California, Ohio or Michigan and provide fast response. Database creation involved, of course, shipping a tape to where the host computer is located.

Actual costs were far higher, often as high as $200 an hour. The program code was written lucidly and simply, avoiding the typical APL-freak's habit of trying to get a whole program into a single line of code. We expected that when ISSPA became a product, we would have to tidy up the code. We soon found that APL heavily penalizes careless programming. An equation calculating a value for 600 school districts cost $160 written one way and $20 written another. The rules change as the DSS becomes a product. The need at the start is fast development which requires "brute force" programming and close attention to the users' needs and perspective. At the product stage, one has to inspect the code.

At one point, we felt that machine costs would be reduced by completely rewriting the code. We contracted with the company whose APL services we were using; they felt sure they could reduce the cost by 50% and spent six weeks "optimizing" the code. There was virtually no improvement; the original code was, on the whole, just as efficient.

Perhaps, as more experience is gained with APL, this problem of "opaqueness" will be resolved, but we were surprised -- expensively so -- by the extent to which highly experienced APL programmers have little insight into the relationship between the source code and machine performance. They do not need this insight for an ad hoc DSS or one used only intermittently. Obviously, as machine costs decrease, the cost problem we encountered will disappear. However, with any computer product, some effort to optimize efficiency is necessary. We suspect that this will be difficult for "problem-oriented" higher level languages for at least the next few years.

Despite these problems, associated not so much with the development as with the consolidation of ISSPA, APL provided the expected advantages. In particular, the programming cost for a new user command is indeed incremental with an extremely low fixed component. For one user, we developed a major new command, which was based on ideas he had got from using ISSPA and which added an important policy concept to school finance analysis. It was "working" in a day; he estimated that at best, it would take three months for the state education programmer's department to implement a similar capability. He was quite willing to put up with minor blemishes in the routine in exchange for such responsive service.

We estimate that about 800 programmer hours of effort have gone into ISSPA. Of course, the system is much more powerful than the initial version, but even so, the figure is painfully close to Brooks' estimate that the final development effort will be nine times the coding effort.

From the few case studies which describe the extension of a DSS to a product, it is clear, in retrospect, that our experiences are fairly typical (see, for example, Alter's discussion of a DSS for media planning).[41] We have given this paper the subtitle of the Mythical Man-Month Revisited. Six months ago, we assumed it would be the Mythical Man-Month Defeated.

8. Conclusion: Guidelines for Building DSS

In Section 1, we stated that one aim in developing ISSPA was to see if the DSS field is now at a point where one can define reliable guidelines for building DSS. Obviously, our experiences are not generalizable. Nonetheless, they confirm much of the often implicit principles of DSS design and the explicit findings of DSS research. We thus feel that we can make some fairly strong assertions:

(1) Adaptive design is essential; any systems analyst, programmer or consultant who wants to build DSS has to know how to:

(a) get started: DSS applications do not come tidily packaged with neat specifications. The middle-out approach provides a means of learning from and responding to the user;

(b) respond quickly: A DSS is equivalent to a system for evolution and learning.

The design structure and programming techniques must facilitate this.

(c) pay close attention to user-system interfaces and outputs: A DSS is a set of relatively simple components that must fit together to permit complex, varied and idiosyncratic problem-solving. The designer needs to get a very detailed understanding of the task to be supported and of the people who carry out the task. The natural sequence and order of priority in DSS development is:

(1) design the dialog;

(2) design the commands in terms of the users' processes and concepts;

(3) define what the user does and sees when this command is invoked; and

(4) work backwards to program logic and data management.

(2) The architecture of a DSS is critical. It must be built on the assumption that there will be substantial evolution and that flexibility is essential.

(3) The development process must be based on techniques and design structures that reduce the fixed costs of programming and the time to respond to users. The trade-offs are complex, and we suffered badly from the high machine costs we incurred in gaining low programmer costs.

(4) Data management involves high software overhead and is the major source of complex program errors.

(5) A good user is essential. As one ISSPA user stated: "After working with a DSS, at a certain point, it takes on a life of its own.". The DSS is man-with-machine; the machine alone is not enough.

The final point to be made is a rueful one. There is indeed no free lunch. The demands in time and effort for delivering a DSS product are as high as for any computer system. The process is more flexible and early progress often dramatically excitingly faster than for traditional data-processing applications, but the 9x still holds.

APPENDIX 1: EXAMPLES OF ISSPA ROUTINES

(Based on problem set in user manual; CHOOSE commands omitted)

1. Prepare a table showing the surplus (deficit) of 1978 special education revenues over expenditures.

```
COMMAND: DEFINE SPECEDAID78 - SPECEDEXP78

ENTER VARIABLE NAME: SPECIAL EDUCATION SURPLUS 78

ENTER SYNONYM (ONE WORD--NO BLANKS): SPECEDSURPLUS78

ENTER PRINT LABEL: SPEC. ED./SURPLUS/1978

ENTER FORMAT CODE: I10


NEW VARIABLE DEFINED.  ACTIVE VARIABLE NO.:  A7

COMMAND:  LIST SPECEDAID78, SPECEDEXP78,SPECEDSURPLUS78


COLUMN FOOTINGS:?   YES
COLUMNS:?   ALL
COMPUTATION TECHNIQUE:?    TOTALS
FOOTING TITLE: (<CR>=NO TITLE.):
oPPo
```

```
                                         SPEC. ED.        SPEC. ED.      SPEC. ED.
                                            AID           OP. EXP.        SURPLUS
                                           1978             1979           1978
                                       ____________   ______________   ____________

  1. 0102 ADAMS                             50,800           47,872          2,928
  2. 0503 BRADLEY                          134,400          124,068         10,332
  3. 0101 CAPITOL CITY                     347,600          354,268         ¯6,668
  4. 0301 DULLES CITY                    1,309,600        1,266,272         43,328
  5. 0501 EASTERN CITY                     539,200          504,488         34,712
  6. 0201 FRANKLIN                          89,600           91,770         ¯2,170
  7. 0202 GARFIELD                          93,600           90,337          3,263
  8. 0504 HURON                                  0                0              0
  9. 0401 IONA                             280,400          285,285         ¯4,885
 10. 0203 JEFFERSON                         70,000           65,110          4,890
 11. 0107 KIRKMAN                          145,200          136,175          9,025
 12. 0204 LAWRENCE                         188,400          174,801         13,599
 13. 0402 MONROE                            34,400           33,030          1,370
 14. 0205 NEEDHAM                          110,400          104,641          5,759
 15. 0403 ONTARIO                           46,000           43,004          2,996
 16. 0103 PARKINGTON                       140,000          140,861           ¯861
 17. 0106 QUEENS                            20,400           19,790            610
 18. 0210 ROOSEVELT                              0                0              0
 19. 0209 SUPERIOR                          48,400           46,936          1,464
 20. 0502 THREE RIVERS CITY                403,200          406,822         ¯3,622
 21. 0208 UPLAND                           134,800          137,831         ¯3,031
 22. 0207 VILLA PARK                        42,000           41,651            349
 23. 0105 WALNUT GROVE                      17,200           16,231            969
 24. 0206 YARDLEY                          152,400          151,601            799
 25. 0104 ZELLERBACH                       134,400          137,086          2,686
                                       ____________   ______________   ____________

                                         4,532,400        4,419,927        112,473

COMMAND:
```

2. Prepare a table showing 1978 total enrollment and expenditures per pupil for all districts with 5,000 or more pupils.

```
COMMAND: DEFINE TOTOPEXP78÷TOTENRL78

ENTER VARIABLE NAME: OPERATING EXPENDITURES PER PUPIL 78

ENTER SYNONYM (ONE WORD--NO BLANKS): EXPPUPIL78

ENTER PRINT LABEL: EXPENDITURES/PER PUPIL/1978

ENTER FORMAT CODE: I15


NEW VARIABLE DEFINED.  ACTIVE VARIABLE NO.:  A18

COMMAND: SELECTIF TOTENRL78≥5000
ENTER DESCRIPTION OF SELECTION:   LARGE SCHOOL DISTRICTS
SELECTION IN EFFECT
10  UNITS CURRENTLY SELECTED

DO YOU WISH TO SEE UNITS CURRENTLY SELECTED?   NO

COMMAND: LIST TOTENRL78,EXPPUPIL78
COLUMN FOOTINGS:?   N
∘PP∘


                                         TOTAL        EXPENDITURES
                                      ENROLLMENT       PER PUPIL
                                         1978             1978
                                      __________   _______________

  1. 0503 BRADLEY                         6,160            1,576
  2. 0101 CAPITOL CITY                   10,859            1,135
  3. 0301 DULLES CITY                    38,720            1,568
  4. 0501 EASTERN CITY                   16,331            1,246
  5. 0401 IONA                            8,243            1,059
  6. 0107 KIRKMAN                         6,229            1,199
  7. 0204 LAWRENCE                        7,750            1,462
  8. 0502 THREE RIVERS CITY              12,505            2,042
  9. 0206 YARDLEY                         6,773            1,185
 10. 0104 ZELLERBACH                      6,064            1,157
```

3. Prepare a table showing the absolute and percent increase in average teacher salaries between 1978 and 1979 for the following districts:

   Bradley - Needham - Huron - Franklin - Roosevelt - Lawrence -

   Yardley - Parkington

```
COMMAND: DEFINE 100×(AVGSAL79-AVGSAL78)÷AVGSAL78

ENTER VARIABLE NAME: PCT CHANGE AVERAGE SALARY 78

ENTER SYNONYM (ONE WORD--NO BLANKS): CHGAVGSAL7879

ENTER PRINT LABEL: PCT. CHANGE/AVG. SALARY/1978-1979

ENTER FORMAT CODE: F11.1


NEW VARIABLE DEFINED.  ACTIVE VARIABLE NO.:   A23

COMMAND: SELECT UNITS
UNIT ('STOP'):    BRADLEY
UNIT ('STOP'):    NEEDHAM
UNIT ('STOP'):    HURON
UNIT ('STOP'):    FRANKLIN
UNIT ('STOP'):    ROOSEVELT
UNIT ('STOP'):    LAWRENCE
UNIT ('STOP'):    YARDLEY
UNIT ('STOP'):    PARKINGTON
UNIT ('STOP'):    STOP
ENTER DESCRIPTION OF SELECTION:    8 DISTRICTS CHOSEN AT RANDOM
SELECTION IN EFFECT
8  UNITS CURRENTLY SELECTED


COMMAND: RANK AVGSAL79,AVGSAL78,CHGAVGSAL7879 BY CHGAVGSAL7879
ORDER (ASCENDING OR DECENDING):?    DESCENDING
COLUMN FOOTINGS:?  N
°PP°
                                 AVG TEACHER   AVG TEACHER   PCT. CHANGE
                                   SALARY        SALARY      AVG. SALARY
                                    1979          1978        1978-1979

  1. 0204 LAWRENCE                 14,071        12,100          16.3
  2. 0205 NEEDHAM                  10,827         9,885           9.5
  3. 0210 ROOSEVELT                11,614        11,116           4.5
  4. 0103 PARKINGTON               13,060        12,775           2.2
  5. 0504 HURON                    13,799        13,580           1.6
  6. 0201 FRANKLIN                 12,003        11,820           1.5
  7. 0206 YARDLEY                  12,160        12,001           1.3
  3. 0503 BRADLEY                 MISSING        12,699       MISSING
```

4. How many districts had 1978 total revenue per pupil greater than $1,500? How many districts had 1978 revenue greater than $1,500, but received no state basic aid in 1978? Which districts were they?

```
COMMAND: DEFINE TOTREV78 ÷ TOTENRL78

ENTER VARIABLE NAME: TOTAL REVENUE PER PUPIL 1978

ENTER SYNONYM (ONE WORD--NO BLANKS): TOTREVPUP78

ENTER PRINT LABEL: TOTAL REV/PER PUPIL/1978

ENTER FORMAT CODE: I10

NEW VARIABLE DEFINED.  ACTIVE VARIABLE NO.:  A9

COMMAND: COUNTIF TOTREVPUP78 >1500

8 UNITS SATISFY CONDITION(S).

DO YOU WISH TO SEE THE UNITS?   NO

COMMAND: COUNTIF (TOTREVPUP78 > 1500) ∧ (STATEAID78 = 0)

5 UNITS SATISFY CONDITION(S).

DO YOU WISH TO SEE THE UNITS?   YES


    1 0102 ADAMS
    2 0503 BRADLEY
    3 0202 GARFIELD
    4 0209 SUPERIOR
    5 0105 WALNUT GROVE
```

NOTES

1. ISSPA is suited to any application where the data consist of a set of planning units (e.g., school districts, employees, buildings or states) and where the analysis involves aggregating, selecting and reporting some or all of the units. For example, ISSPA is likely to be used in the near future as a DSS for planning and analysis of personnel data and for tracking and evaluation of federal research grants.

2. F. P. Brooks, The Mythical Man Month, Addison-Wesley, 1977. Brooks' book is surely the best single discussion of software engineering. There is not room in this paper to do justice to its scope and insight. It covers, among other topics: (1) the distinction between programs and programming systems products (the main topic of this chapter), (2) the non-linear relationship between program size and development effort, (3) the problems of coordination in large-scale software development efforts, (4) the importance of program architecture, (5) the need for independent certification and testing of software, (6) the need for sharp tools (including APL), (7) disciplines for debugging and documentation.

   Brooks was the project manager for OS/360, the operating system for IBM's third generation. Between 1963-1966, about 500 man-years of effort went into OS/360, and at one point over 1000 people were working on it. Brooks' book is both an analysis of what happened and a recommendation of how to avoid similar programming "tar pits".

3. See Garms, Guthrie and Pierce (1978).

4. We have added a third dimention, years, so that future versions of ISSPA will include capability for time series analysis.

5. Most ISSPA users work with either a subset of about eight variables or begin by pulling in a larger number that they then aggregate or combine, using the DEFINE command. A dilemma for DSS designers is how to efficiently and quickly extract the small number of variables a user wants to work with from what is often a very large data base.

6. P. G. W. Keen, "Decision Support Systems: Translating Useful Models into Usable Techniques", Sloan Management Review, Summer 1980.

7. The Gini coefficient and Lorenz curves are standard measures of disparity of income or wealth. See Garms, et al.

8. Our colleague David G. Clark joined us in developing ISSPA around this point. He has played a major role in translating ISSPA from a program to a product, especially in the areas of training, documentation and marketing.

9. David A. Ness, who has probably been the most important single contributor to DSS design techniques, developed the term "middle-out" to describe this approach. Middle-out development (in contrast to top-down and botton-up) relies on prototyping, "breadboarding" and designing-by-using. Ness's ideas and experience have been a major influence on our work.

10. Courbon and his colleagues have carefully tracked the costs of DSS development and provide tetailed data on the manager's and designer's time involved.

11. James Phelps, Associate Superintendent in the Department of Education in Michigan and William Harrison, Legislative Assistant to the Education Review Committee in Ohio, were invaluable to us. The literature on the need for user

involvement in systems development seems to have a very passive concept. In adaptive design, the user is active and indispensable. Dr. Phelps and Dr. Harrison became designers of ISSPA by being responsive, creative users.

12. There should have been a manual; its absence caused occasional irritating and unnecessary problems (e.g., "is it CROSSTABS...WITH or BY?"). One problem adaptive design causes is that since the DSS is constantly evolving and version "0" is designed with change in mind, there is no stable system to document. It is thus essential to build as much of the user documentation into the DSS as is possible. One approach we are considering is to store the text of the user manual on disk so that it can be accessed directly from ISSPA.

13. P. G. W. Keen, "Decision Support Systems: A Research Perspective", CISR Papers, Sloan School of Management, MIT, 1980.

14. The literature on diffusion of innovations indicates that "early adopters" are generally part of an elite that is self confident and willing to break norms and traditions. One reason for seeking out such people as the first users of a DSS is that they are effective contacts and crusaders for the wider organization. As well as helping design the DSS, they in effect sell it.

15. See Berne (1979).

16. See Gerrity (1970), Stabell (1974), and Keen and Scott Morton (1978). All these authors point out that management science tends to focus only on prescriptive maps, ignoring the need for support. In teaching graduate students to be DSS users or designers, much of the course material must concentrate on descriptive conceptions of decision making. One cannot improve something one does not understand.

17. See Keen and Clark (1980).

18. See Keen (1980 b).

19. Tukey (1977) defines a range of innovative, mainly graphical techniques for analysts to really look at their data before committing themselves to analytic methods.

20. McNeil (1977) provides APL and FORTRAN source code for many EDA techniques. His output formats are generally clumsy; here again, we concentrated on making these useful routines more usable.

21. See also Mehtlie (1979).

22. See Carlson and Sutton (1974).

23. See Keen (1980 a). All references to Keen in Section 5 relate to this paper.

24. See Ness (1975).

25. See Keen (1975) and Bennett (1976).

26. See Brooks (1975), p. 46.

27. See Stabell (1974) and Andreoli and Steadman (1975).

28. See Keen and Clark (1977).

29. See Bennett (1977).

30. See Artman (1980) and Sigle and Howland (1979).

31. See Blanning, also Contreras (1979).

32. See Berry (1977).

33. See Keen and Wagner (1979). IFPS (Interactive Financial Planning System) is a product of Execucom, Inc., Austin, Texas.

34. See Contreras and Skertchly (1978).

35. The use of semi-colons allows users to operate in an "expert" mode where they do not have to wait for ISSPA to type out the standard instructions or questions. This enhancement was provided in response to user demand.

36. See McKenney and Keen (1974), Keen (1980 a), and Henderson.

37. See Alter (1980).

38. See EDP Analyzer, January, February, March 1979.

39. See Nanus and Farr (1964) and Weinwurm (1965).

40. See Ness (1976).

41. See Alter (1980), p. 225. This DSS was built by Ness and a colleague and illustrates middle-out in practice.

***

BIBLIOGRAPHY

Alter, Steven L., Decision Support Systems: Current Practice and Continuing Challenges, Addison-Wesley, Reading, MA, 1980.

Andreoli, P. and J. Steadman, "Management Decision Support Systems: Impact on the Decision Process," Master's thesis, M.I.T., 1975.

Artman, Ira B., "Design and Implementation of a Decision Support System for Hospital Space Management," MS Thesis, M.I.T., 1980.

Bennett, J., "Integrating Users and Decision Support Systems," In J.D. White (ed.), Proceedings of the Sixth and Seventh Annual Conferences of the Society for Management Information Systems, pp. 77-86, Ann Arbor: University of Michigan, July 1976.

__________, "User-Oriented Graphics Systems for Decision Support in Unstructured Tasks," IBM Research Lab, 1977.

Berne, R.M., and L. Steifel, "Concepts of Equity and their Relationship to School Finance Plans," Journal of Education Finance, Vol. 5, Fall 1979.

Berry, P., "The Democratization of Computing," Paper presented at Eleventh Symposium Nacional de Systemas Computacionales, Monterrey, Mexico, March 15-18, 1977.

Blanning, R., "The Functions of a Decision Support System," The Wharton School.

Brooks, F.P., The Mythical Man-Month, Addison-Wesley, Reading, MA, 1975.

Carlson, E.D. and J.A. Sutton, A Case Study of Non-Programmer Interactive Problem-solving, IBM Research Report RJ, San Jose, CA, 1382, 1974.

Contreras, L., "Linguistic Design of Decision Support Systems," Unpublished manuscript, Southern Mehtodist University, 1979, (to be a chapter in Bennett).

____________, and R. Skertchly, "A Conceptual Model for Interactive Systems," APL Users Meeting, Toronto, September, 1978.

Courbon, J.C., Grajew, J., et Tolovi, J.,Jr. "L'approche evolutive dans la mise en place des systemes interactifs d'aide a la decision," Papier de Recherche IAE - Grenoble, no. 78-02, Institut d'Administration des Entreprises, Universite de Grenoble II, Jan., 1978.

Garms, W., J.W. Guthrie, and L.C. Pierce, School Finance: The Economics and Politics of Public Education, Prentice-Hall, 1978.

Gerrity, T.P., Jr., "The Design of Man-Machine Decision Systems," Ph.D dissertation, M.I.T., 1970.

Grajew, J., and J. Tolovi, Jr., "Conception et mise en oeuvre des systems interactifs d'aide a la decision: l'approche evolutive," Ph.D thesis, 1978, Universite de Grenoble.

Henderson, John, "Experimental Studies of Decision Support Systems," work in progress, Florida State University.

Keen, P.G.W., "Computer-Based Decision Aids: The Evaluation Problem," Sloan Management Review, vol. 16, no. 3, pp. 17-29, Spring 1975.

__________, "Computer Systems for Top Managers: A Modest Proposal," Sloan Management Review, vol. 18, no. 1, pp.1-17, Fall 1976.

__________, "Decision Support Systems: A Research Perspective," CISR Paper, Sloan School of Management, 1980a.

__________, "Decision Support Systems: Translating Useful Models into Usable Technologies," Sloan Management Review, Summer 1980b.

__________, and D.G. Clark, "Computer Systems and Models for School Finance Policy Making: A Conceptual Framework," research report to the Ford Foundation, August 1978.

__________,"Simulations for School Finance, Survey and Assessment," research report to the Ford Foundation, 1980.

__________, and J. Wagner, "DSS: An Executive Mind Support System," DATAMATION, November, 1979.

McKenney, J.L. and P.G.W. Keen, "How Managers' Minds Work," Harvard Business Review, Vol. 52, no. 3, pp. 79-90, May-June 1974.

McNeil, D.R., Interactive Data Analysis, Wiley - Interscience, 1977.

Methlie, L., "Data Management for Decision Support Systems," Unpublished Paper, Norwegian School of Economics and Business Administration, 1979. (for Bennett book)

Nanus, B. and L. Farr, "Some cost contributors to large-scale programs," AFIPS Procedings SJCC, 25 (Spring 1964), pp. 239-248.

Ness, D., "Interactive Systems: Theories of Design," Joint Wharton/ONR Conference - Interactive Information and DSS, Dept. of Decision Sciences, The Wharton School, University of Pennsylvania, Nov. 1975.

Sigle, J. and J. Howland, "Structured Development of Menu Driven Application Systems," APL QUOTE QUAD '79, ACM, June 1979.

Stabell, C., "On the Development of the Decision Sypport Systems as a Marketing Problem," Paper presented at the International Federation for Information Processing Congress, Stockholm, Sweden, August 1974b.

Tukey, J., Exploratory Data Analysis, Addison-Wesley, 1977.

Weinwurm, G.F., "Research in the management of computer programming," Report SP-2059, System Development Corp., Santa Monica, 1965.